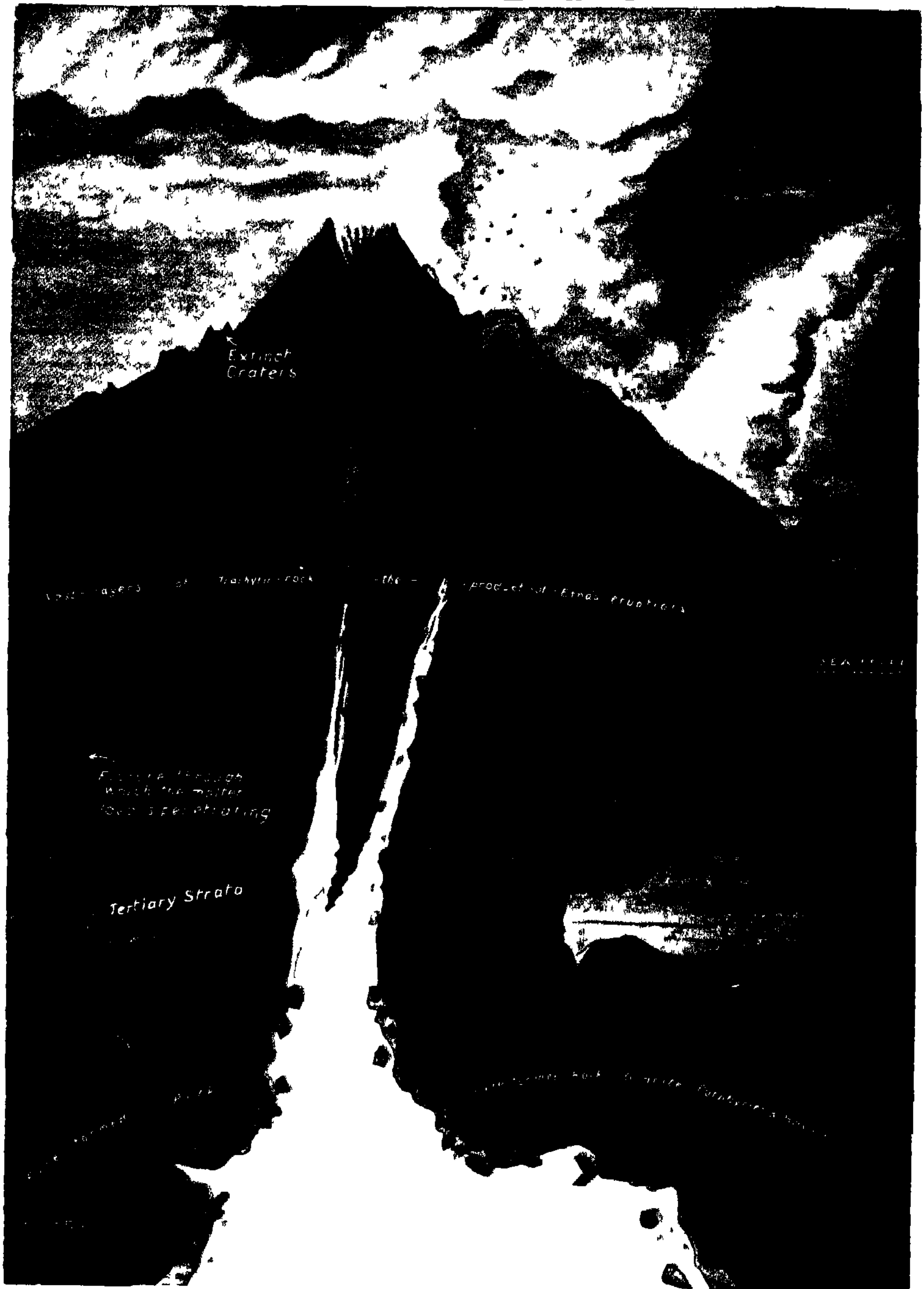
HOW EARTH'S CENTRAL FIRES BURST OUT



A section of the historic volcano Etna—supposed in classic times to be the entrance to Pluto's kingdom—showing how molten lava, formed by the liquefaction of the lowest rocks, is projected upwards through fissures in the superincumbent strata until it escapes through the main crater or through subsidiary cones and so keeps adding to and raising the mountain as it cools on the surface

The Book of

POPULAR SCIENCE

The Wonders of Modern Discovery
The Triumphs of Inventive Genius
The Story of all Created Things and
the World They Live In

EDITED BY

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VOLUME
II

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CONTENTS OF VOLUME II

MICHAEL ANGELO'S THINKING MAN

It may possibly have taken six million years, some authorities think, for human life to reach the summit on which man now stands—six million years, that is, to bridge the gulf between far-away man and modern man whom Michael Angelo so finely embodied in this statue of Lorenzo de Medici.

DID EARLY MAN LIVE IN TREES?

Did Robert Louis Stevenson's
"Probably Arboreal" Really Exist?

WHERE, WHEN AND HOW CAME THE FIRST MAN?

BY way of summary let us restate that man may be considered as having arisen, either through "special creation" or as having "evolved" from some lower form of life. Some people accept the special creation origin; others believe in the evolutionary development of man because of the many anatomical similarities found in the lower and fossil animals. In keeping with our early promise we shall now put before the reader some of the various interpretations placed on these two theories of the origin of man. Therefore, let us open this chapter with the following quotation from Robert Louis Stevenson's "Memories and Portraits":

"There is a certain critic, not indeed of execution but of matter, whom I dare be known to set before the best. A certain low-browed, hairy gentleman, at first a percher in the forks of trees, next (as they relate) a dweller in caves, and whom I think I see squatting in cave mouths on a pleasant afternoon to munch his berries — his wife, that accomplished lady, squatting by his side; his name I never heard, but he is often described as Probably Arboreal, which may serve for recognition. Each has his own tree of ancestors, but at the top of all sits Probably Arboreal; in all our veins there run some minims of his old, wild, tree-top blood; our civilized nerves still tingle with his rude terrors and pleasures; and to that which would have moved our common ancestors all must obediently thrill."

Thus wrote Stevenson, and the scientific writer may be grateful that he didn't write more of such speculative ideas, which are quite inaccurate and express more than strict science can ever hope to prove.

Some still believe that the first men were "Probably Arboreal," but made adventure upon the ground, that they had enemies and especially snakes to fear; and that their remote descendants share that fear still. Their other evidence of our arboreal descent is very various. New-born babies have been found to possess an incredible power of grasping objects and supporting themselves thereby, which, according to these people, they soon lose, and which none can emulate in later years. However, one has but to watch the agility of the present-day circus performer to quickly convince himself that the act of "grasping" and "swinging" by the hands can be developed and retained in the human throughout a much later period of life than that of mere infancy. True, in the lower types of mankind the arms and the shoulders are much more highly developed than the legs and the length of the arms is greater in proportion to the length of the body, similar to what we find in the arboreal apes. But the foot of man is a kind of compromise. It is far from being perfectly adapted to the ground, for it is most inadequately protected, and civilized man has always had to provide artificial protection for it and has always paid the price of corns and distortion of joints in consequence. Yet his foot has ordinarily little power of grasping, and man is certainly not four-handed. The anatomists report, however, that the sole of his foot contains four distinct layers of complicated muscles, most of which serve no present purpose, but which may be survivals from the time when the organ was used for grasping. Boys love to climb trees, and

have no small natural skill at it, but one has only to watch them to realize how unsuitable the lower limbs are for it.

According to the followers of Stevenson, "Probably Arboreal" was an athlete, if we may judge at all by modern gibbons, some of which can throw themselves as much as forty feet from the branch of one tree to catch the branch of another. At the same time they would have you remember that the use of the legs for upright progression involved their strengthening in bone and in muscle, and the arms had to lose something by way of compensation. But man's arm boasts a muscle with two "heads," or places of origin, which is accordingly called his "biceps," whereas the biceps of the modern agile gibbon is really a quadriceps, for it has no less than four heads. Man is therefore not justified, historically, in attempting to acquire the arm-power of a gibbon, who, indeed, mainly ran to arm and had a very light and slender body to carry.

In what the diet of our first ancestors probably consisted

Our modern controversies on hygiene and habit add interest to the speculation as to the habits of the very first men. It may be that they were vegetarians. Their diet may have consisted chiefly of nuts and fruit. The young were, of course, fed with their mother's milk, and this feeding may have been very prolonged. But the adults were probably vegetarian; and we must disabuse ourselves of the idea that they were savage, club-armed creatures resembling the pictures of the gorilla.

If our ancestors were really vegetarians, like vegetarians in general they must have been of a different temper: not aggressive, probably timid, though light-hearted enough when free from danger, and doing no more harm to other animals than may perhaps have been accomplished by birdnesting. Birds' eggs would be welcome diet, and would be the only probable exception to their primitive vegetarianism. Those who believe that man's ancestors lived in trees just as the gibbon does, claim that boys, whom they call "monkeys," climb trees for birds' eggs still. However, this doesn't prove their contention, for boys climb trees merely to collect the eggs and preserve the shells. They do not *eat* the eggs.

These same people further state that the teeth of apes and of man are fundamentally distinct from the carnivorous type, but are excellently suited for nuts and fruit, but this is not the case, for we have teeth for cutting and tearing, as well as for grinding. We are not entitled to note these facts as conclusive in the controversy regarding man's diet. They are important and highly instructive, but it must be remembered that man is man, not "Probably Arboreal"; that his body and his habits are now profoundly modified; and there is a possible argument, on the other side, to the effect that life on the ground, with the opportunities it offers for more concentrated and stimulating fare, such as animals would provide, makes a great difference between the ape and man.

Were our ancestors no bigger than a child is today?

That argument is probably unsound, but it has to be met; and the wisest course would be for us to decide these dietetic questions on their own merits without reference to evolutionary speculation. Otherwise it would not really be difficult to argue that man should be all manner of inhuman things. This caution applies equally to the athleticism and to diet.

The modern gibbon is a comparatively small animal. An arboreal animal must imperatively keep down its weight if it is safely to keep up its body. Descendants of animals "who have taken to the ground" have lost the necessity for small size, and accordingly we find the gorilla, which may be five feet six inches high. This is of interest in more ways than one. If coming down to the ground enabled the gorilla to grow in size and strength of body and legs, as distinguished from the strength of arm which was so essential in the trees, he doesn't show it by any weakness of his "arms." But it has also been associated with a notable change in the span of life.

Longevity has long been an obscure subject, and much comparison of the different forms of animal life, even as lately as the work of Metchnikoff, has left it still obscure, though less so. But one generalization may perhaps be permitted here.

The great advantage in more ways than one of being a giant

Comparing forms that differ in size, say, man and monkeys, small birds and large birds, small tortoises and large turtles, increase in size goes with an increased span of life — longevity comes in with giantism. An elephant, a large mammal, will live 150 years or more; a dog or cat, a small mammal, lives 15 years at the most. The underlying explanation of this fact is yet to be found, but the fact itself interests us.

HOW BRAIN DEVELOPMENT HAS CHANGED THE SHAPE OF MAN'S SKULL

These three skulls of (1) an Australian native (2) a negro, and (3) a European show how the form and size of the human skull have been gradually changed by the brain development

Man is a giant, so far as his body is concerned; and accordingly his span of life may run to a century. The gigantic size of man — for he is definitely a giant when looked at historically — has another great advantage in that it enables him to maintain his bodily temperature with much greater ease than is possible for a small animal, which has so large a surface in proportion to its mass, and cools so much more rapidly. It cannot be believed that a denuded tropical animal of the size of the gibbon could have survived and thrived in temperate zones as man has survived. Hence, could man have come from the same stock as the gibbon?

When, therefore, the modern athlete envies the astonishing skill and capacity of a couple of gibbons having a game, he should remember that he is a giant, relatively to them, that this is greatly to his gain on the whole, that the price he has paid for it in diminished agility and relative arm-power is a small one, and that to attempt to equal the gibbon in this respect is to go back upon his distinctive physical humanity. He has enormous advantages of his own in other respects, and he should remember that he is human. His arms are not used for locomotion, but for higher purposes, and he should be grateful for the longevity which he has gained, so that he is in his physical prime at twice the age of an aged gibbon.

The gibbons are inhabitants of forests, their long arms enabling them to swing themselves from bough to bough, which they do to wonderful distances and with extreme agility. They cannot move with ease or great rapidity on the ground, yet when they make the attempt they walk more uprightly than any other ape, stretching out their arms on each side or, even more frequently, overhead, to balance themselves, with the hands hanging from the wrist. They never creep on all fours, like the child on its hands and knees, and they sleep at night curled up in a ball. In captivity they display gentleness and a high degree of teachability. They also learn to eat cooked food, though their natural diet consists mainly of fruit and birds. They have loud cries, expressing emotions, but does this prove any relationship to man or that man, like the gibbon, once lived in trees?

Turning again to man, it must be remembered that he is living from the first by his wits. That is the mark of man from the beginning until today. We must also disabuse our minds of the picture of the open-mouthed gorilla advancing upon his enemy with a club. Be it never forgotten that we are dealing with a creature which was remarkably intelligent and original and curious. This is a creature, too, which has exceedingly serviceable hands; and these hands are freed from locomotion, and simply long to use their liberty by doing more than ever in the way of picking up and touching, and examining, and even digging and constructing — just in the fashion for which children are daily reproved in modern times.

To these characters of body and of intelligence, notably of insatiable curiosity — which reaches such heights in the modern man of science — we must add those of imitation, and the power of learning by experience. The common description of man's first parents as being solitary or as living in small families, after the fashion, or alleged fashion, of the gorilla, is probably quite erroneous. It is much more likely that our ancestors were decidedly or, at the least, potentially, social and gregarious, as we should expect in creatures so imitative and so susceptible to suggestion. Hence, we can begin to see how the observations and successful experiments of one or two "born leaders" would soon modify and advance the practice of the first men as of their latest representatives. The original minds are wanted first, and then the receptive and imitative faculty in the crowd.

Whatever the sequence and manner of events, certainly the contention that man did somehow come into being from an ape-like and arboreal ancestor is without proof, and when we have attempted to trace the possible manner of this evolution of man, so far as his habits are concerned, we may pass on to face three great questions which evidently remain.

The first two of these problems, the birthplace of man and the antiquity of man are of old standing, and have reached some degree of solution. As for the problem of the origin of man in the sense in which Darwin wrote of the origin of species, that question also has reached a new phase.

The birthplace of man was probably in the Old World. Like the light and other things, he probably came from the east and westward the course of his empire and the light of his mind have taken their way. Man in the New World is perhaps an immigrant, not a native. We do not find fossil remains of man or of anthropoid apes here, though the New World abounds in noble fossils of a thousand other kinds. There are no anthropoid apes here now, but only tailed monkeys. The aboriginal inhabitants of the New World appear to have reached it, we think, by traveling from northeastern Asia and entering it from the north. Land may have been continuous in those days between the continents. On this theory we might expect all the aboriginal and native — but not indigenous — men of the New World to be yellow skinned and to partake of the characteristics of the Mongol. That is, indeed, what some investigators find, not only in details of anatomy, but also in

LITTLE ANIMALS THAT MAY HAVE CROSSED THE PACIFIC BEFORE MAN WALKED THE EARTH
The two types of tapirs shown above, both from the same stock, are found to-day in Malaysia and in some parts of the Western continent. They must have crossed the Pacific Ocean, a distance of about 5000 miles [illegible] gone is now deep sea, as shown in this section of the Pacific. How did they cross? The probable answer is that they crossed by land which then connected the American and Australian continents.

habits and culture. They therefore say that the first settlers in America were yellow; but if this theory be true, how are we to explain the fact that, at the time of the discovery of America, only "red men" were found on the Western continent?

We may turn to the Old World, then, for the probable birthplace of man, and in the Old World certainly to Asia, where we found the "ape-man," and where we find the gibbons and the orangs today. But there are anthropoids in Africa also, the chimpanzee and the gorilla, which are found nowhere else. There are also very primitive human beings in Africa. Thus it may be suggested that man had more than one birthplace. Perhaps one kind of man, and that superior, was born in Asia, and another, inferior, in Africa.

This view of the multiple origin of man is not now held by high authority. All the evidence is against it. Far more probable, not to say proved, is the view that certain lowly types of man, who suggest a beginning in the places where we find them, are degenerate, and represent ancestors of higher type who settled there. This is one of the great controversies not to be settled in a paragraph, but apparently we have no choice but to believe in the single origin of the human species, and that origin probably took place in Asia. Needless to say, any further suggestion must be highly speculative. The discovery of the "ape-man" in Java suggests a more definite site. But at this point we plainly have to reckon with geology, and what it may teach us as to the past. For we are speaking of very ancient times, and no one can prove that the configuration of land and sea was then as we find it today. There is some reason to suppose that such islands as Java and Sumatra and Borneo represent the remains of a now submerged continent. It thus may be that the true birthplace of man is now an ocean bed.

MAN DOES NOT POSSESS THE STRENGTH AND AGILITY OF THE LOWER ANIMALS, BUT HIS MIND AND HANDS HAVE GIVEN HIM MASTERY OVER ALL CREATED THINGS

The next question, as to the antiquity of man, is no less interesting. Of course, we here depend again upon geology. We trace back human records as far as possible, and we compare those, and the levels at which they are found, with present-day conditions. But when this is done we are bound to refer to the geologist for his estimates of the antiquity of those various deposits in which man has left his first marks.

The estimates vary from time to time, but they always vary in the same direction, which is that of extension. Not so very long ago one-third of a million years was a figure which gained credence on the grounds then available, and indeed that seemed a long time; but it is little enough when compared with modern reckonings of the antiquity of the earth's crust and the life it supports.

Dr. Keith and other students have rejected even this figure as inadequate, and Dr. Keith has suggested something like six million years as representing the antiquity of man.

The formidable mystery of how man came into the world

We have studied man's forerunners, and the probabilities of the sequence between them and him, and we have clearly seen that he has anatomical resemblers in the animal world of the present and of the past. But the fact remains that the abyss between man and these creatures is wide and profound.

When the lowest forms of man have been observed, and the highest forms of animals, and when the utmost allowance is made for the advantages of training and society in the one case and their absence in the other, and when all the resemblances between the human and the anthropoid brain, the human and the anthropoid habit of mind, have been generously estimated, the *how* of man's origin is scarcely one whit less formidable than ever.

He still is seen to be unique and inimitable, and we are apt to go back to the "special creation" explanation.

If a natural explanation is alone to satisfy us, we must choose, it now seems clear, between two. The choice need not be determined by any time advantage belonging to one or other, for modern geology, and the records of fossils, allow us an unimaginable space of time; and if we are offered a theory which demands enormous ages, it may have them. One of the theories does make this demand; and the time has now come when we may venture to call it the classical theory, for it depends upon the unaided application of the Darwin-Wallace doctrine to the human case. That doctrine asserts that new species come into being very gradually through the inheritance and slow accumulation of minute variations in many successive generations, such variations being chosen by "natural selection" because they favor the survival of the individual and the race. In the case of man, we naturally think of the brain, which matters everything. We are to suppose that, in the case of this creature, living by his wits, those wits would be stringently chosen by natural selection. The "brainiest" would survive and leave children, and thus, at last, our ancestors would be human. Granting that there is an enormous distance to traverse between the two, geology will allow enormous periods of time for the process.

Did man come about by slow degrees or by a sudden change?

Here we shall not presume to choose between this theory and the newer one; our present business is to state both fairly. The newer one takes regard of the recent evidence, supplied by the followers of Mendel and others, which suggests that, contrary to the view of Darwin, species arise more commonly, if not always, by quite abrupt changes in type. This view would not require anything like so much time as the other. According to it, a comparatively small number of abrupt changes in the brain might occur, subject to the laws of what is called "variation," and these changes, being favorable, would be spared by natural selection. They would resemble the production of such a "sport" as a nectarine by a peach tree. Thus we should regard present-day man not, indeed, as a sport of the higher apes, but as a sport from the original stock of man. The production of sudden human varieties is consonant with all the known facts of other species, and may have thus occurred. Natural selection would then favor the survival of such sports, because of the survival value of superior brains and superior instincts with which man seems to have been endowed since time immemorial.

BREATHING LIFE AND DEATH

The Truth and Some Illusions about
Fresh Air and the Life in the Open

WHAT A "CHANGE OF AIR" REALLY MEANS

ON every ground we should begin our statement of the demands of health by discussing the need of air. It is the most urgent of all vital needs; the reader will never reach the end of this paragraph, or start another, unless he breathes an atmosphere which will sustain his life. Further, air does not receive its due in discussions on health. Most people's interest in health questions concentrates upon diet. As for those who purvey health, or its means, they are bound to lay stress chiefly upon the special foods or drugs they sell, or upon their special methods of "physical culture." The food may be eaten, or the dumb-bells swung, in an atmosphere which does fifty times the harm that they can do good, but no one minds. Unfortunately from our point of view, the air is colorless, nor are there any color differences between pure air and foul air; and "what the eye doesn't see, the heart doesn't grieve for."

But for the hygienist, who has no concern whatever but to give the advice which most promotes health, the question of air is paramount. Though, in large degree, air can be had for nothing, the hygienist is just as interested as if it had been captured by a group of capitalists, and the various qualities had to be paid for at the market price. In those conditions, in the introduction of the monetary issue, every one would agree that the question of air was almost the first and last so far as health is concerned. Here we must make a great effort, and try to get up an interest in air on its own merits, though it is not for sale, and though the great majority of people can have all they need for the asking.

Another obstacle to the proper appreciation of this question is that it is not really controversial. If it could be made a party question it would attract people, but on the whole we agree about air. People invent "fasting cures," but they do not invent suffocation cures. The need of air is beyond question; and public sentiment in this country, though by no means throughout the world, is wholly in favor of fresh air. The most determined non-ventilator, who spends his life shutting windows, and to whom the breath of heaven is miasma and abomination, will pronounce himself an enthusiastic believer in fresh air. Only, he does not like "draughts" Similarly, we all say we like music, though 90 per cent of us want to talk during the second half-minute of any real music. Public opinion is in favor of air and music; and we conform thereto.

One of the purposes of this chapter will be to show that the man who manifests his love of fresh air by spending his time in excluding it from his precincts does himself and others great harm; and that the difference between lip-service and nostril-service to fresh air is all the difference in the world. It is immensely worth while to pay the real homage, which is not with the open mouth of protestation, but with the open nostrils of inhalation. Here the hygienist does not require to stand up against public opinion and common practice, as in the case of not a few popular habits. He has the easier task of showing how public opinion may really get what it believes in, and of warning it against imitations.

Relatively unimportant chemical differences between kinds of air

It might seem to be the only proper fashion in which to start that we should make a tabular statement of the differences between pure air on the one hand, and the many kinds of foul air on the other. Chemists have analyzed many kinds of air, and it is possible to state the composition of city air and country air, mountain and sea air, day and night air, "subway" air, sewer air, average bedroom air, and so forth, with much accuracy. Many pages could be taken up with the statement and comparison of these differences between pure air and foul.

But the remarkable fact, which has baffled most commentators, is that the differences in composition which the chemist describes seem ridiculously inadequate to account for the differences which the doctor sees in people who breathe these different kinds of air. The doctor knows that in certain kinds of air people die, and in others they live. He reports to the chemist and asks for comparative analyses, and the chemist reports back again that the percentage of oxygen or of moisture is a fractional point higher in the one case and lower in the other. Either we must revise our notions of this subject altogether, and find some fact of health and ill-health which we have hitherto forgotten, or we must suppose that the chemist, though he can measure some of the things in the air, is somehow unable to measure, or even to discover, the most important of all.

How the mosquito which feeds by night has misled popular belief

It is the writer's belief that the chemist is not at all to blame, and that the fault lies with the doctors, who have forgotten, in this connection, what they have themselves discovered and really know so well. If we put together the doctors' discovery and the chemists' analyses we shall have the science of this subject in our hands. The key to it is to be found in the remarkable history of the widespread disease called "malaria," from the Italian words meaning "bad air."

This is not the place for a systematic account of malaria. We can learn all we need if we simply know that this disease, for ages attributed to the breathing of "mal' aria," or "bad air," is now known to be due to invasion of the blood by a minute animal parasite, which is inserted by the bite of the female of a particular kind of mosquito. The mosquito begins to feed at nightfall, and those who expose themselves to the "dangerous night air" are thus liable to contract malaria.

At one stroke, therefore, modern discovery upsets the oldest and apparently most clearly evidenced of beliefs. The difference between the day air and the night air which produces malaria is that the night air is inhabited by a particular mosquito. We must restate our beliefs.

The destruction of the old superstition about night air

It is probably safe to assert that the habits of this mosquito account for the almost universal superstition about night air. The chemist is entirely at a loss — and naturally so -- when he is expected to find any objection to night air, so far as its composition is concerned. On the contrary, everything he reports is in its favor. It contains a less proportion of carbonic acid gas, which does not sustain human life, but is the most important of its waste products. It contains a slightly higher proportion of oxygen, by which we live.

These differences chiefly depend upon the fact that there is much less combustion, by fires and furnaces, going on at night, so that carbonic acid gas, the chief product of combustion, is therefore added to the air in less quantity than in the daytime. Still more to the advantage of night air in cities is the fact that it is very much less dusty, owing to the diminution of traffic. Compared with ordinary day air, night air may almost be said to be filtered of the solid impurities which we call dust, but which include under that term not only genuine dust, but also a multitude of microbes and their spores, adhering to mere dust and blown about with it for us to breathe.

ONE OF THE CHIEF ENEMIES OF HEALTH

THE TONGUE OF A COMMON HOUSE FLY, ENORMOUSLY MAGNIFIED

One of the worst enemies of health in the whole world is the common fly, which carries infection and spreads disease in all manner of unexpected places This remarkable photograph of the tongue of a common house-fly enormously magnified is by J J Ward

The infection that lies in night air in malarial countries

All along the line, then, night air scores, which is none the less satisfactory, seeing that one has to breathe during the night, and all air at night is night air. And the universal superstition is traced to the habits of a female mosquito. There may have been other elements in it, such as the more superstitious fear of darkness, or of ghosts, but there is little doubt that it is the mosquito which is responsible for the fear of night air — a fear which the prevalence of malaria has so entirely justified.

It now behooves us, with this revelation in our minds, to look again at the whole question of air, and the differences between the different kinds of air. We have found that, so far as chemistry and the filter can show, night air is far superior to day air, but exposure to it, over a wide area of the earth, means exposure to infection.

After much study the present writer is satisfied that the hygienic differences between different kinds of air depend far more upon what they mean in the way of infection than upon anything else. All over the malarial parts of the earth, the best kind of air — in itself — is the worst, because it means exposure to infection. And since the broad difference between health and disease is most often due to the difference between non-infection and infection, we may guess that the observed facts of fresh and foul air, city and country air, and so forth, in our part of the world, are due to differences in exposure to infection far more than to anything else.

Broadly speaking, the open air is the safe air from this point of view. But, of course, if the open air carries aërial insects that distribute microbes or such parasites as that of malaria, the safe air is the closed air. The risk of infection decides the question. In this part of the world we preach the value of open air; and in the tropics we preach that the open air is dangerous, especially at night. There is no contradiction. In the tropics the open air is the infected air, so far as the chief tropical diseases are concerned. Here it is the closed air that is infected.

In some of the finest shops in America the saleswomen can be seen early in the day pale and tired, without appetite, simply because the air is not changed often enough. Even the largest room does not contain sufficient air to last through a whole night without being changed. The increase in this country of the use of screened sleeping-porches must have had a favorable influence on the general health.

The sunlight which is fatal to all forms of parasite life

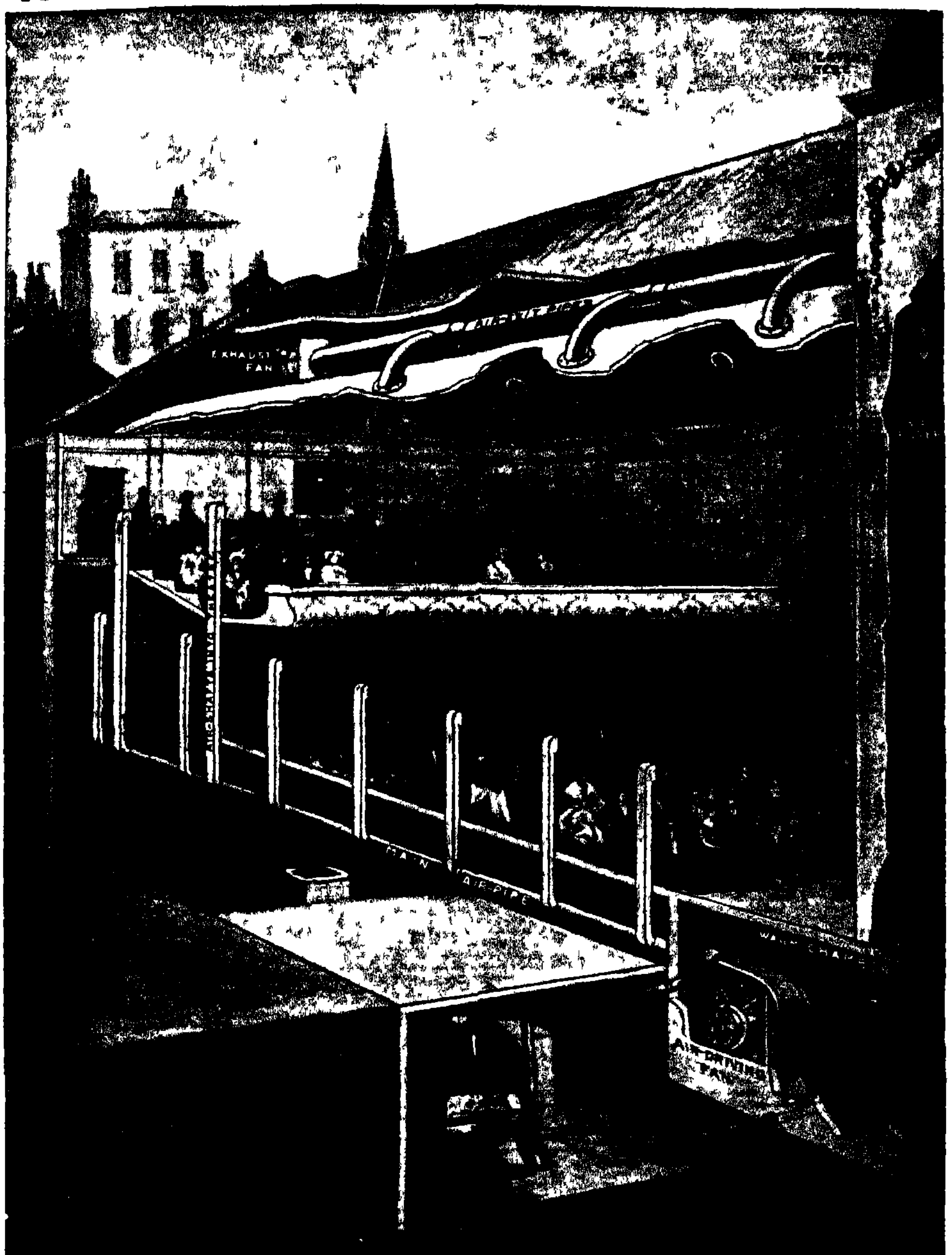
Dangerous microbes can flourish in the open air, but they must take the precaution of being safely housed inside the body of some insect. If not so housed, they cannot flourish in the open air. It means too much oxygen for their tastes, too much movement — whereas what they like is to find suitable stuff to prey upon, and to stay there — and, above all, it means exposure to direct sunlight, which is fatal, rapidly and invariably, to all forms of parasite life, microbe or any other. The whole nature of any kind of parasite is to creep away from the sun and the air, into the darkness and the warmth of the unlucky body which it has marked for its prey.

Microbes have no wings, and cannot fly; and all the old views about air-borne infection must be abandoned. What we have so long called air-borne infection is almost always, if not always, insect-borne or dust-borne. As for infected dust, which is a real danger, one grain of it in a room is more to be feared than a thousand grains out of doors, for out of doors the light and the constant exposure to moving oxygen rapidly destroy it, whereas indoors, under cover of the darkness, it may harbor dangerous forms of life for years.

Sir Almoth Wright hit the nail on the head when he asked why fresh air should be credited with such unique virtues in the case of consumption and not in other diseases, if it be simply that fresh air strengthens resistance, and enables the patient to throw off the disease.

The answer to this question is quite clear to the expert students of consumption, and of all the other infections that occur and are spread through the breath.

THE FRESH AIR-SUPPLY OF A PUBLIC BUILDING



THE WAY IN WHICH A MOVING PICTURE HOUSE IS VENTILATED

The development of the moving picture house, with its several almost continuous "sessions," would be a great danger if care were not taken to maintain a pure air supply. This section of one of these buildings shows how the air enters at the top, flows down an enclosed shaft into a chamber kept at a high temperature, and is then distributed through the air-shafts in the walls. A suction fan draws all the used air out at the roof, and a river of fresh air is thus constantly flowing through the theater.

The microbe of consumption which dies in the open air

The sanatorium for consumption has its invaluable use in isolating infectious persons, and thus protecting other people, and it would have this use if it did nothing else. But it does much else. It very often cures the patient, and almost always it greatly prolongs his life. The chief reason is that the open-air structure of the sanatorium, and the open-air life there, are death to the microbes of consumption; and therefore the patients, who may be quite able to recover from the infection they already have, but could not recover from repeated doses of it, are free to get well.

From LePrince & Orenstein's *Mosquito Control in Panama*, © G. P. Putnam's Sons

APPLYING OIL TO ROADSIDE DITCHES IN THE CANAL ZONE

There are no new microbes to inhale; and very likely the old ones, already inhaled, can be dealt with by the patient's defenses, if they are not reënforced. In former days, patients often recovered when they were sent on long sea-voyages. It was not the sea air that cured them, but the absence of microbes from sea air. As for more advanced cases, in which the sanatorium, failing to cure, at any rate prolongs life, the explanation is that the germs of septic infection cannot survive under the conditions of a sanatorium, all light and air, and no dust; and therefore the patient's lungs are not done to death by having those septic microbes added to the consumption microbes.

Undoubtedly it is the "open air" that does the good, saves the lives, or prolongs them; but our naive idea that this depends upon some difference in the composition of the open air and indoor air is just as inaccurate as the idea that malaria was due to some poisonous quality in the night air derived from the "exhalations of swamps." Mosquitoes breed in swamps, and microbes breed in indoor dust. Infection is the key to the facts in both cases.

Wherever men have ceased to defame "night air," but have killed mosquitoes, in malarious countries or anywhere else, the disease has disappeared. The secret of success is to know what to go for.

For ages men talked about night air, and died of malaria; now they get rid of the night mosquitoes, and are well. If we thought less about the air in itself, and killed the day-fly as men kill the night-mosquito in the tropics, we should save our babies.

Surely enough has now been said to prove that we formerly looked rather unintelligently at these questions. All the advance in our knowledge of disease for the last thirty years has gone consistently in the direction of disproving that any gases or constituents of the air cause disease, and of proving that diseases apparently due to the air, and diseases apparently conveyed by air, are due to microbes, and are conveyed by insects. The discovery of the microbe of consumption, and its conveyance by expectoration, and hence by dust, from the sick to the sound, means no less a revolution than the discovery of the mosquito's part in malaria. It means that if we only have the sense to control and prevent infection, people may be cured and their friends protected, if we once grasp the fact that it is not the air that matters, but what is put into it. Dust matters, dirt matters, animal excrement — in which flies breed and feed — matters, dark rooms, with darker corners, small windows, that let in little light, spitting, which infects the dust our clothes and boots and skirts gather and bring indoors, where its microbes are in safety, and we are therefore in danger — these are the things that matter.

Not the air that matters, but what is put into it

Furthermore nothing is more unexpected or significant than the facts that, when we examine the different kinds of air, the differences are found to be absurdly small, and that when we try experiments in order to see what the effect of these differences upon our bodies may be, we commonly find no effects at all. The composition of the atmosphere of our planet necessarily varies in many ways at all times. But on the whole it remains astonishingly uniform. The wind, and what is called the "diffusion of gases," by which all the gases in a mixture tend to mix themselves equally throughout the mixture — these two agencies constantly tend to keep the composition of the air uniform. It is morally certain that, ninety-nine times out of a hundred, when people go away for "change of air" — an ancient phrase invented for its obvious convenience when doctors knew less — they either get no change of air that any chemist can measure in any way, or such change as they do get is of no importance whatever.

What really happens when we go for a "change of air"

In any case of so-called "change of air" it is certain that the air is the very thing in which there is the least change. There is change of scene, of room, of people, of associations bodily and mental, change of food, and above all, and more important than all else put together, change of thought, change of the mind's air; but so far as the air of the lungs is concerned there is no change worth mentioning, except, indeed, that, as a rule, when people take a "change of air," they do make the change that they spend far more of their time in the open air. Thus, the person liable to influenza and bronchitis and colds and tonsillitis, and the consumptive also, persons who have been living largely in rooms richly infected with the germs in question — for which of us disinfects his house after having had a cold? — get away from these risks, real though invisible, in which they live, and profit accordingly.

Within the last few years a number of new researches have added force to the general argument of this chapter. There remained several diseases, such as typhus fever, and the pellagra of the Italian peasant, and several more which did seem to depend more probably upon some kind of injury wrought through the air than anything else.

The air that is the same everywhere, and the different things it carries

It was not really the "confined air" of houses or the "devitalized air," as unscientific people distinguish themselves by saying, that caused people to fall sick of these "low fevers" and their allies. Air has nothing to do with these illnesses, neither confined air nor devitalized air, nor night air, nor slum air.

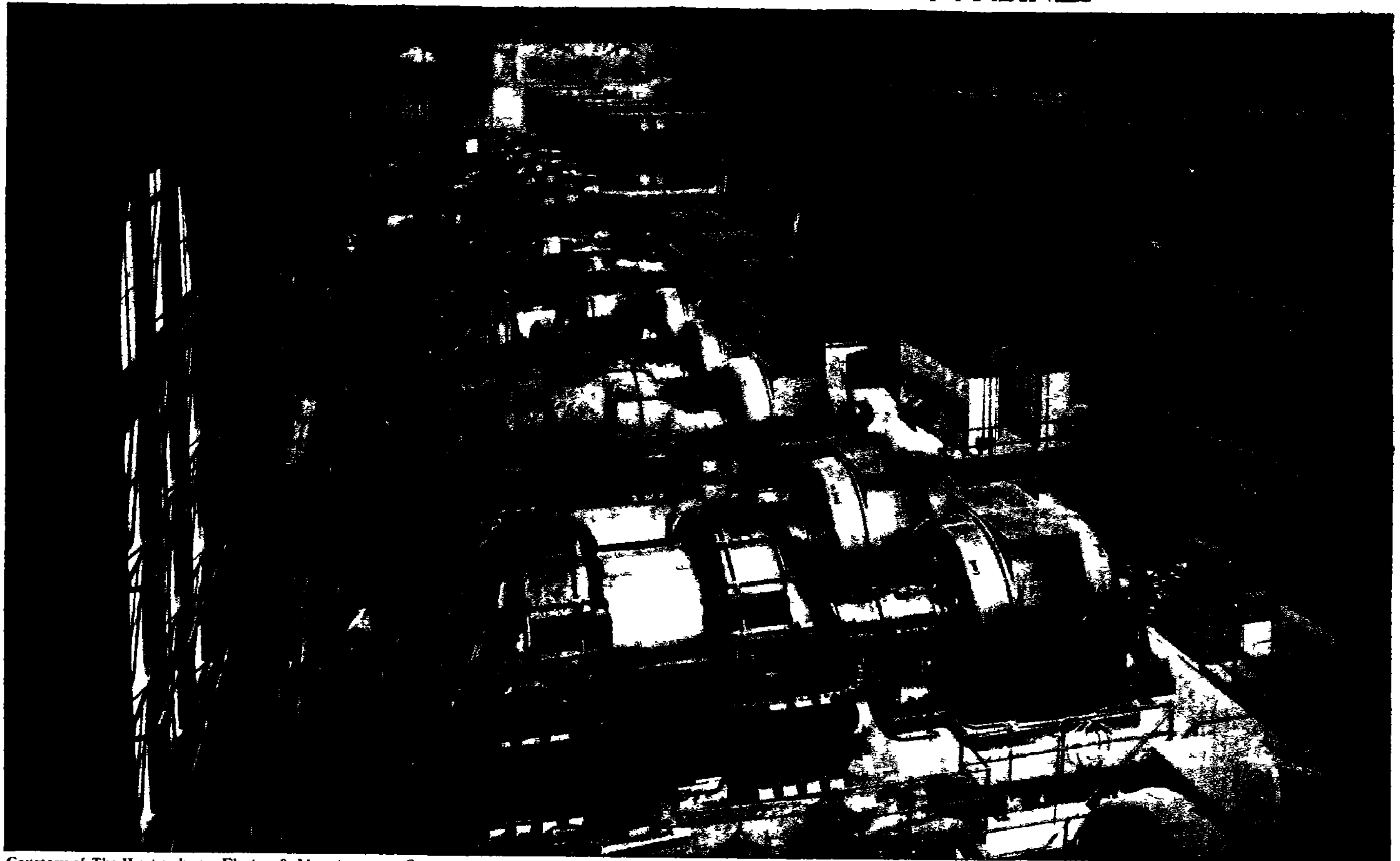
Here again let us always remember, it is microbes and insects that are man's greatest enemies. These low fevers are microbic diseases of which the infection is conveyed by insects — after the parallel of malaria. The insects are things like blackbeetles and cockroaches, and other disagreeable and deadly creatures flourishing in dirt and darkness and in slums which are the swamps of cities, where disease is bred for all classes, as malaria is bred in the swamps of the tropics.

The air and light that are the enemies of dirt everywhere

The value of ventilation, of fresh air and light in the modern prison, and in the model tenement, and the garden suburb, is beyond all question; but we must know that this is not because there are magical differences between one kind of air and another, but because air and light are enemies of dirt, because they help to sterilize it, and because they help to reveal it, so that the housewife sees it and removes it.

Now we have cleared the air of its microbes and insects, we can see how to study it on its own merits. It has its own merits, and its own questions are important and interesting, but its inhabitants are vastly more so, and their existence had to be recognized before we could proceed farther.

ONE OF THE LARGEST STEAM TURBINES



Courtesy of The Westinghouse Electric & Manufacturing Co

ONE OF THE POWER STATIONS OF NEW YORK INTERBOROUGH RAPID TRANSIT CO

Showing a 30,000 kilowatt steam turbine in the foreground, and, in the center, a 70,000 kilowatt t... one of the largest in the world In the back-
ground are a number of reciprocating st am engines but their power all tog th

A NEW ERA IN THE STEAM WORLD

The Greatest Step Forward in the Use of Steam Power since the Days of Watt and Stephenson

HOW THE TURBINE CAPTURED THE WORLD

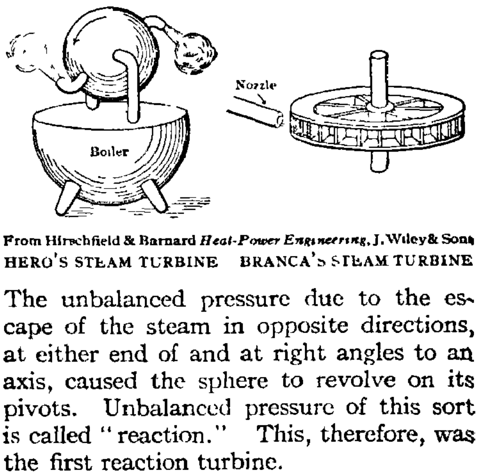
A VISITOR is looking into an engine room containing several large reciprocating engines, each with its multiplicity of moving parts, some rotating, some sliding back and forth and others rocking to and fro. The general impression conveyed to the mind is that of a large collection of complicated moving machinery, dangerous to approach and difficult to keep clean. The visitor crosses a passage and enters a room where the same number of steam turbines are producing the identical amount of power.

The contrast is startling, to say the least. This room is much smaller and, instead of a great complicated mass of moving machinery, a few box-like affairs made of iron and steel, somewhat cylindrical in shape, are distributed about the floor. The room is very clean and comparatively quiet, the only noise being a low humming which is rather soothing to the ear. At the first glance, it would appear that no moving parts are visible, but on closer inspection, the rapidly revolving shafts catch the eye.

In the first room, a half-dozen men were busily engaged in cleaning and oiling the engines: here, perhaps, two men, with apparently very little to do, but with watchful eyes, are easily taking care of the same amount of power.

These are some of the visible contrasts, and as they appear to be of considerable importance showing up the steam turbine as something in advance of the reciprocating engine, let us look more closely into this new type of prime mover and see how it is able to do the work of the older reciprocating engine to such advantage.

It is interesting to note that the idea of the steam turbine first appeared about 200 B.C., long before any one considered the possibility of using steam in a reciprocating engine. At that time, a Greek named Hero constructed an engine consisting of a hollow sphere mounted at its axis upon two pivots, one of which was hollow and served as a supply pipe for steam coming from a boiler below. The sphere was fitted at the top and bottom with two pipes bent in opposite directions through which steam escaped.

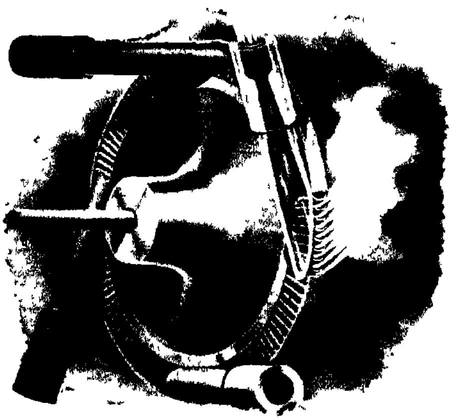


From Hirschfield & Barnard *Heat-Power Engineering*, J. Wiley & Sons
HERO'S STEAM TURBINE   BRANCA'S STEAM TURBINE

The unbalanced pressure due to the escape of the steam in opposite directions, at either end of and at right angles to an axis, caused the sphere to revolve on its pivots. Unbalanced pressure of this sort is called "reaction." This, therefore, was the first reaction turbine.

Besides the principle of reaction, that called "impulse" is of great importance in connection with the steam turbine. The first impulse turbine was constructed by an Italian named Branca about 1629 and consisted of a wheel to the rim of which buckets or blades were attached. Against the blades was directed a jet of steam, thus causing the wheel to revolve.

At intervals during the next 250 years, various attempts were made to construct a machine which would use one or the other or both of these principles of impulse and reaction successfully, but without result. The first patent in this line in the United States which gave any promise of success was issued to one Avery in 1848. This small reaction machine had a few years of apparently successful operation, but soon withdrew in favor of the then well-known reciprocating engine. The first steam turbine with permanent commercial success came from the brain and hands of Dr. Gustaf De Laval, a native of Sweden, in 1882. This was a simple impulse turbine. Two years later, in England, Sir Charles Parsons introduced the well-known type of so-called reaction machine that now bears his name.



THE DE LAVAL TURBINE WHEEL AND NOZZLES

This diagram illustrates how the steam acts in a De Laval steam turbine of the simple impulse type

Everyone is familiar with the old flat-bladed water-wheel which, turning slowly under the impulse of the stream of water flowing over the dam, furnished power for sawing logs, grinding wheat, etc. That is, perhaps, the simplest type of water turbine, very clumsy and inefficient, of course.

If you pause some day on the bank of some one of the many swiftly flowing streams at the foot of many of our high mountains, particularly in the West, you will probably see a building with a large pipe extending from high up on the hills down to and entering its side. Inside the building you will find that the pipe ends in what is apparently a fire hose nozzle so placed inside of a casing that the issuing jet of water strikes with all its force against peculiar, cup-shaped buckets fastened to the rim of a wheel, thereby causing the wheel to revolve rapidly. This is a water turbine of the impulse type usually known as a "Pelton" wheel.

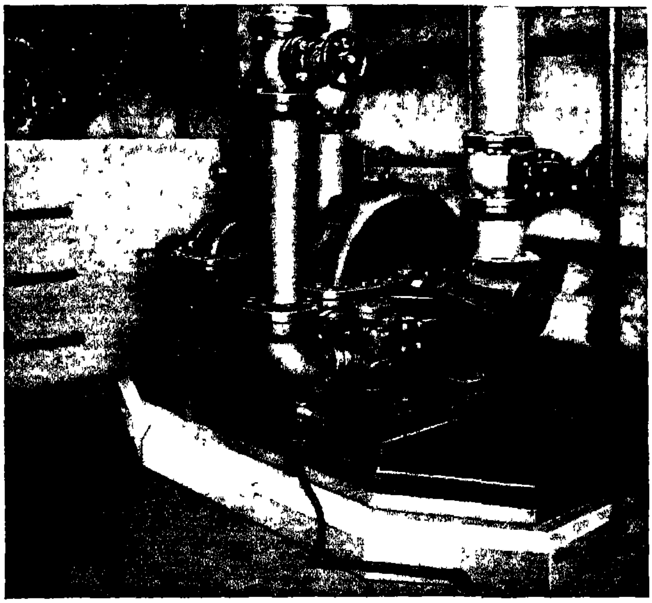
Now the impulse type of steam turbine in its simplest form is, in many ways, similar to this Pelton wheel. Of course, steam is an elastic fluid and will expand or increase its volume as the pressure grows smaller. This causes the steam to move much faster than water under the same conditions and requires different shaped nozzles and blades. The turbine introduced by De Laval in 1882 was of this simple impulse type, and in a later, slightly modified form, it is shown in the illustration, the action of the steam being clearly indicated. It consists, as may be seen, of a single wheel or rotor upon the rim of which are fastened a large number of curved blades or vanes. The nozzles which direct the steam in a proper manner against the blades and in which all the expansion of the steam occurs are plainly shown.

It is interesting to note the manner in which the steam does its work in this turbine. Entering the nozzles at the existing boiler pressure, the steam experiences a drop in pressure and an increase in volume, which changes indicate a decrease in the heat energy originally stored up in the steam. This decrease in the heat energy of the steam results in its greatly increasing its velocity energy, so that when it leaves the nozzle it is at the lowest pressure in the system, but it has a very high velocity. The nozzle, then, is really a machine for changing as much heat energy as possible into velocity or kinetic energy.

The impulse of this rapidly moving steam against the blades of the rotor is what produces the mechanical power for which the turbine is used. The vanes of the rotor are so shaped that as much en-

ergy as is practicable is given to the wheel before the steam leaves on the opposite side from which it enters. As the steam on leaving the nozzle is already at the lowest pressure in the system, it is evident that this same low pressure (usually 12 or 13 pounds below the pressure of the atmosphere) will exist on both sides of the rotating wheel. This makes it unnecessary to provide for end thrust, as has to be done in other types.

Both theory and practice tell us that in order that a water turbine like the Pelton wheel should run at full efficiency, a point on the center line of the wheel bucket must travel through space at one-half the speed of the jet of water leaving the nozzle. Now the energy which produces this jet velocity in a water wheel comes from the "hydraulic head," a term meaning the distance through which water must fall to produce such energy. Heat, as has been said, is the source of energy in the steam turbine and here are produced jet velocities as high as 41 miles a minute. It is, of course, obvious that no machine could be built which would stand a speed of half this jet velocity, although theoretically this is the proper speed. So with this type of machine described above, where there is only one expansion and one set of blades, the speed is made as high as mechanical construction will safely allow. This on the smallest size turbine will be about 30,000 revolutions per minute and yet it is below the proper theoretical best speed. It is very plain that even such a speed is far too great to be of any commercial value, so in this type of turbine it is reduced, by gearing, to one-tenth of its value before it is used with any machine and even then its magnitude is such that it is serviceable only for such machines as high-speed dynamos and centrifugal pumps which are, of course, directly connected to the slower of the two revolving shafts. On account of the speed, it is possible to build these machines only in units not exceeding 500 horse-power.



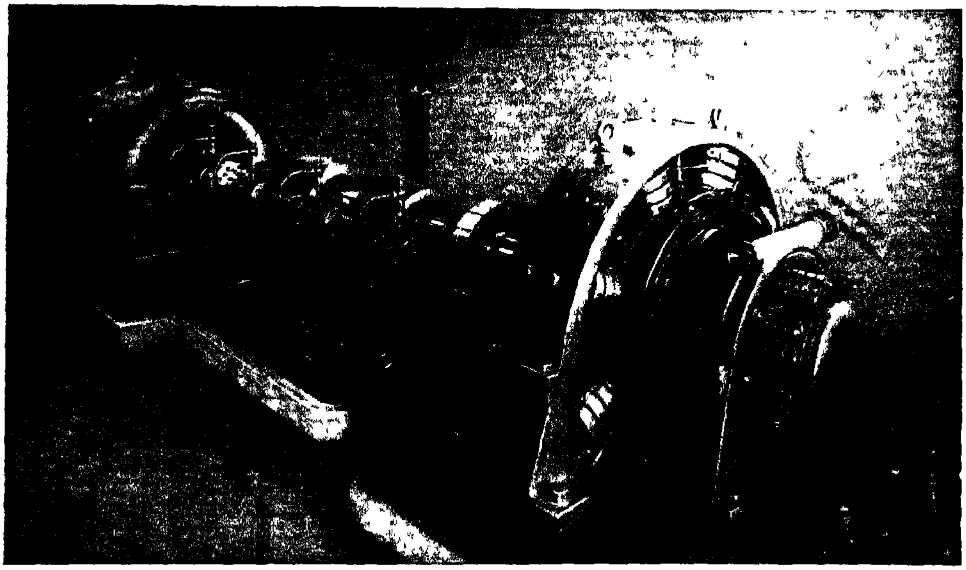
SMALL DE LAVAL STEAM TURBINE AT WORK

The small De Laval turbine, in the foreground, is driving a centrifugal pump, in the rear, which is used to pump the feed water into a steam boiler

A modification of this type which permits the use of more reasonable speeds is the multi-stage turbine. This compounding may be done in two ways. The expansion instead of all taking place in one nozzle may be divided among several. In place of a single set of moving blades a number of sets of alternate moving and stationary blades may be used. The first method transforms the heat energy into that of velocity in a number of steps instead of one; the second gives this energy to the wheel gradually on successive sets of blades in place of the single set described above. Both these methods used singly or together make it possible to produce the same power with a turbine at a much lower speed and these multi-stage principles are employed in many types. Practically all small turbines are of the impulse type as this principle lends itself better to small sizes than does that of reaction.

In the impulse turbine, the blades rotate while the nozzles are stationary. A pure reaction turbine in theory carries the blades stationary on the casing while the nozzles are on the rotating member. In a reaction water turbine, the stationary blades act as guides to properly direct the water on to the wheel where the vanes act as nozzles and where the water, after being directed against the wheel vanes, leaves, its reaction against these moving blades furnishing the power which drives the wheel.

of the different steps are rows of curved blades arranged similarly to those on the De Laval turbine. This drum, shown in several illustrations, fits with extreme exactness inside of a casing as shown in the accompanying picture. On the inside of this casing are fastened rows of fixed vanes arranged to have the same diameters and so placed that they fit in between the rows of moving blades making an alternation of first a row of moving blades and then one of fixed blades throughout the whole length of the turbine.



DE LAVAL MULTI-STAGE IMPULSE TURBINE

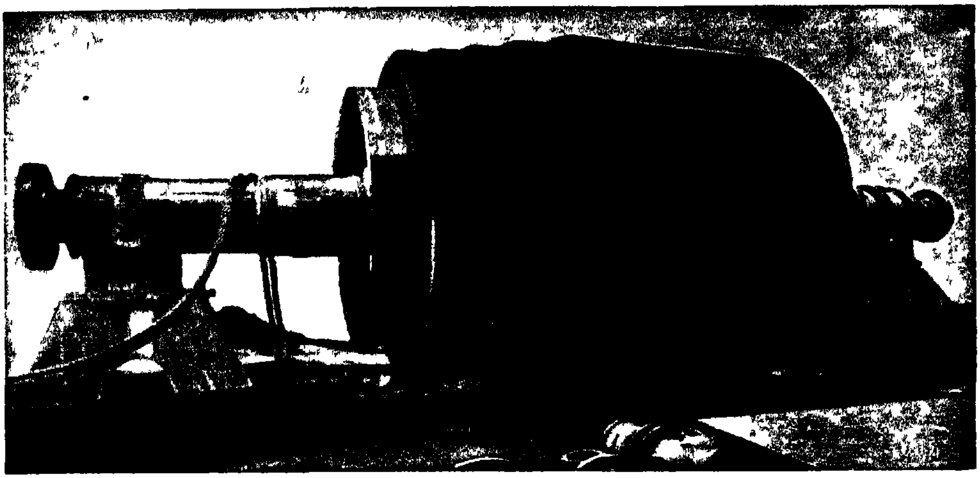
The turbine, at the rear, is driving the direct current generator, in the foreground. On account of the difficulty in constructing direct current generators to run at commercial turbine speeds, it is necessary to have the turbine on one shaft and the generator on the other with reduction gears between. These spiral cut gears can be plainly seen near the middle of the picture.

The steam turbine invented by Sir Charles Parsons, and manufactured in this country under the name of Westinghouse Parsons, is popularly known as a reaction turbine. As a matter of fact both the principles of impulse and reaction act to produce its powers.

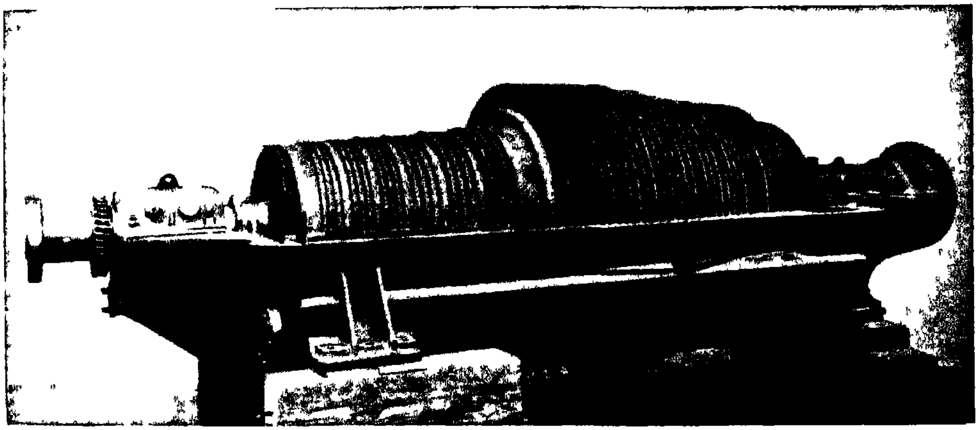
In place of a wheel with a single row of blades, this turbine has for its rotating member a long cylindrical drum mounted on a shaft. The diameter of the drum increases in a series of steps, these usually being three, four or more, according to the size of the machine. Fastened to the circumference of the rotor, on each

The action of the steam in this machine is as follows: Entering through a valve which is operated by the governor to keep the speed constant, the steam instead of expanding in a nozzle passes directly to the first ring of stationary blades; from these it strikes the first row of rotating blades, moving them by impulse. The shape of the passage between these blades is such that the steam expands, making these blades really a set of moving nozzles. In passing from these moving vanes to the next set of stationary ones the reaction of the expanding steam on the blade-nozzles gives added impulse to the rotor.

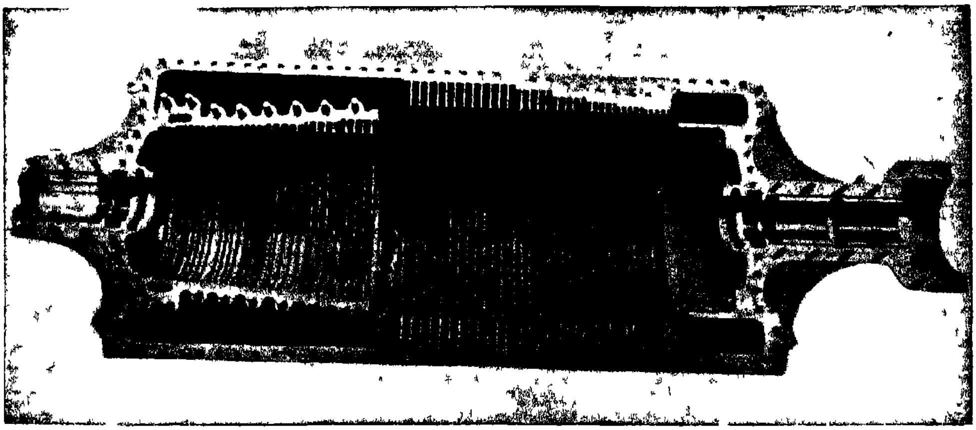
THE DRUM THAT DRIVES A CITY AT SEA



ONE OF THE *MAURETANIA* TURBINE DRUMS WITH ITS HUNDREDS OF THOUSANDS OF BLADES



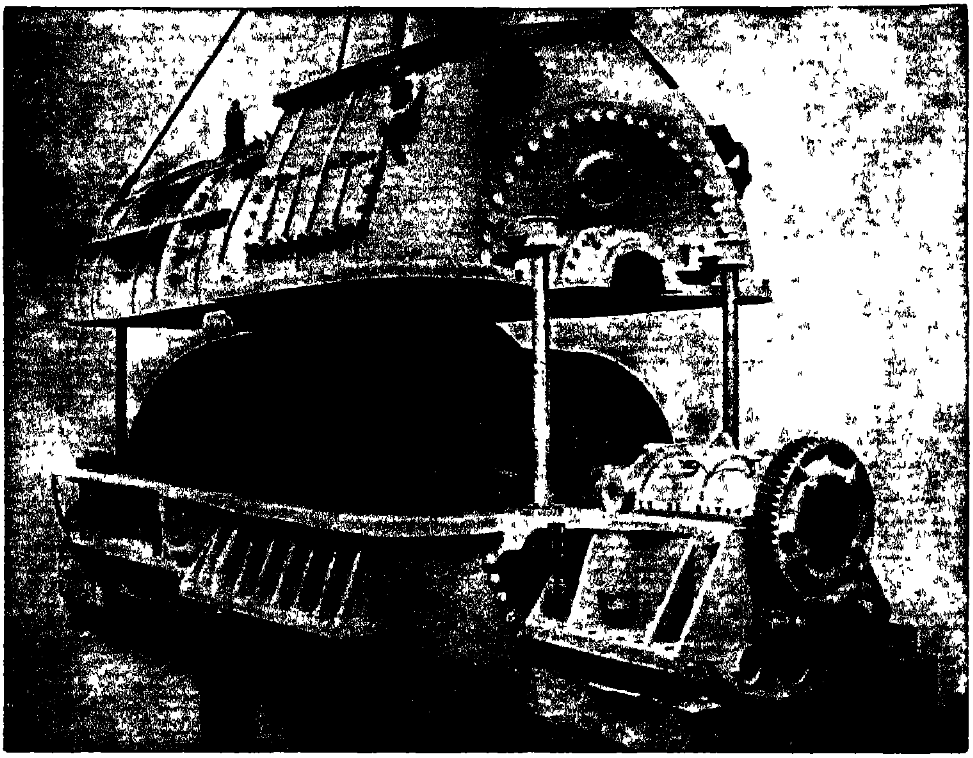
THE DRUMS FIXED IN POSITION IN THE LOWER HALF OF THE CASING OR CYLINDER



LOOKING DOWN UPON THE LOWER HALF OF THE TURBINE CYLINDER, WITH ITS RINGS OF FIXED VANES

The turbines of a huge liner have more than a million blades, each one fixed by hand. The force of the steam is so great that one tiny vane, or blade, weighing only half an ounce, will exert a pull of three-quarters of a ton when the steam is playing upon it. The meaning of the word "turbine" is "whirlwind."

The increase in the length of blades and the diameter of the drum, together, cause a continuous expansion of the steam in its passage from one set of blades to another throughout the length of the rotor. So that steam entering one end at a high boiler pressure leaves the other at the lowest pressure in the system, which is considerably below that of the atmosphere.



ENCLOSING THE GREAT DRUM OF THE TURBINE IN ITS UPPER AND LOWER CASINGS

This expansion of the steam causing a gradual change from heat energy to velocity energy makes it possible for this turbine to revolve at a much lower speed than can one of the simple impulse type. A common speed for a three-stage turbine is about 3600 revolutions per minute.

While there are many other makes of turbine on the market almost all of them are modifications in one way or another of these two types.

It would seem as though in this wonderful age of scientific achievement, the steam engine, and here we include the steam turbine, would have reached a high degree of perfection, and this is true in some respects. When, however, we consider the heat energy which is available in the steam supplied to an engine and the useful work which is done by the machine, we see how great a chance for improvement still remains. The diagram on page 396 shows this in a very clear way for the turbine

In comparison, it is interesting to notice that the performances of the best designed reciprocating engines and steam turbines show very little difference in economy. Where, then, are the advantages of the turbine? They will be briefly taken up in what follows

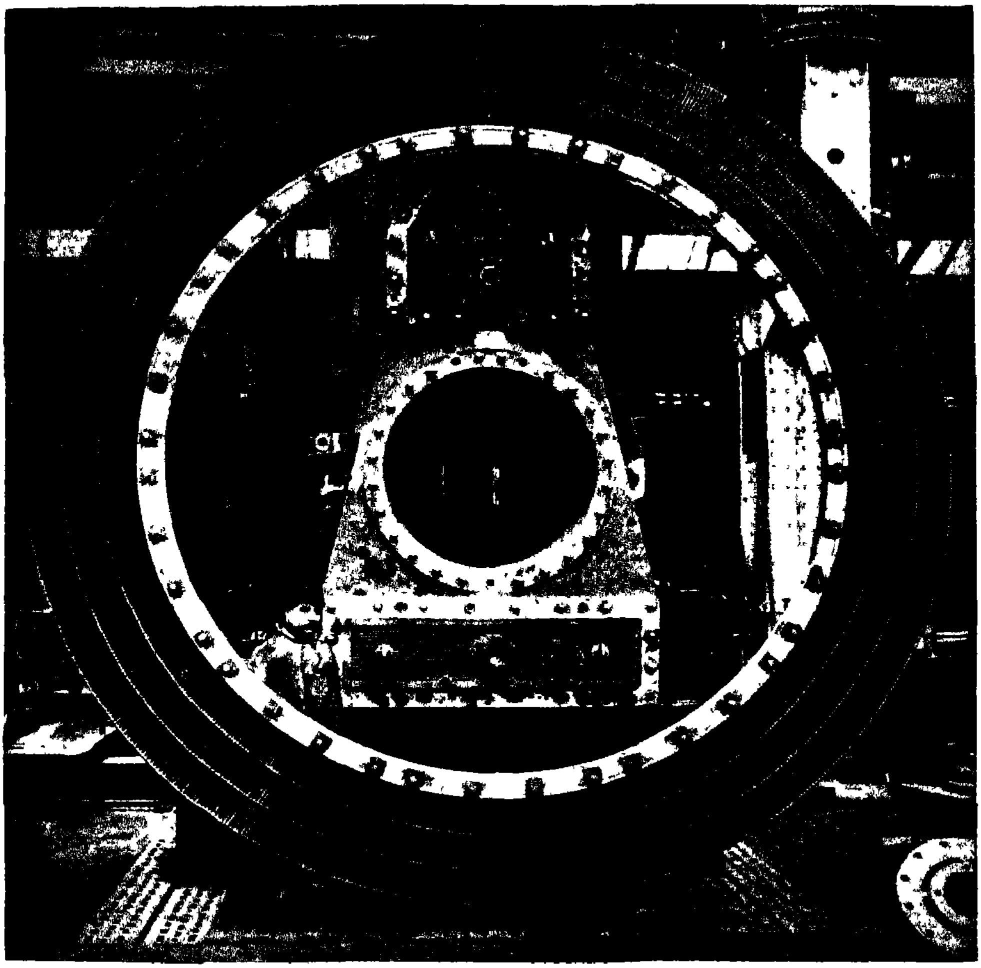
Much less floor space is occupied by the turbine alone. This, however, is partly offset by the fact that the auxiliary apparatus, condenser, pumps, etc., are larger and hence take up more room.

Unlike the reciprocating engine, the rotating parts of the turbine are perfectly

balanced, thus producing a more constant speed and making vibration and wear very small quantities. This, of course increases the life of the machine and practically does away with all repairs. The shaft bearings are the only parts of the turbine which need lubrication and this keeps the steam free from oil which is a great advantage when it is returned to the boiler.

While at its rated load, a good turbine will not show any appreciable advantage in economy over a good reciprocating engine, yet if that turbine be run at loads less or greater than normal, it will use less steam than an engine under the same conditions. In other words, its good economy is nearly constant for all loads while that of the reciprocating engine is not.

As to first cost, a turbine alone without its auxiliaries costs less than a reciprocating engine; but taken with the condenser, pumps, etc., there is very little difference between the two. The cost of upkeep, repairs, attendance, etc., is much less for the turbine than for the other engine.

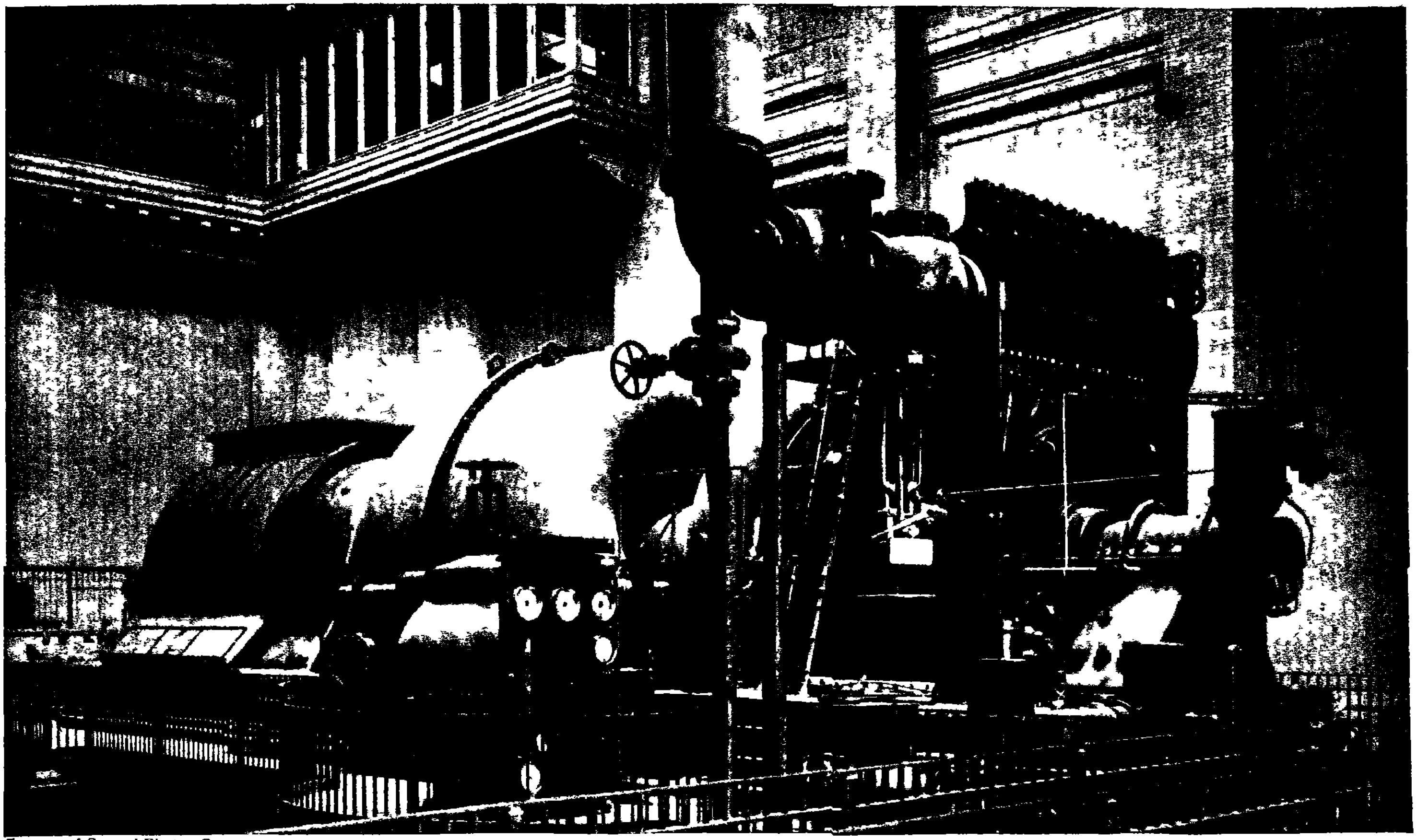


A RING OF THE *MAURETANIA'S* TURBINE-DRUM, WHICH WHIRLS ROUND AT 720 MILES AN HOUR

This shows how wonderfully the little blades are fixed upon the big drum of a turbine, ready to seize the mighty force of the steam that rushes upon them, sometimes as fast as 48 miles a minute, a rate sufficient to go round the world in 8¼ hours

The last few years have seen great progress in turbine design. It has shown itself in new combinations of the different

A GIANT STEAM TURBINE THAT WILL LIGHT AN ENTIRE BIG CITY

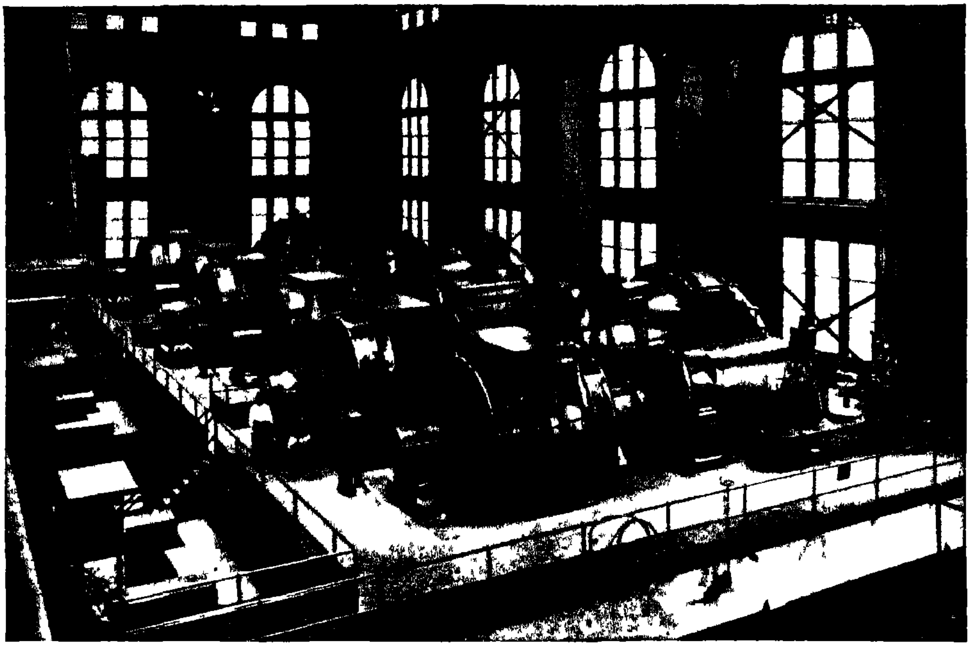


Courtesy of General Electric Co.

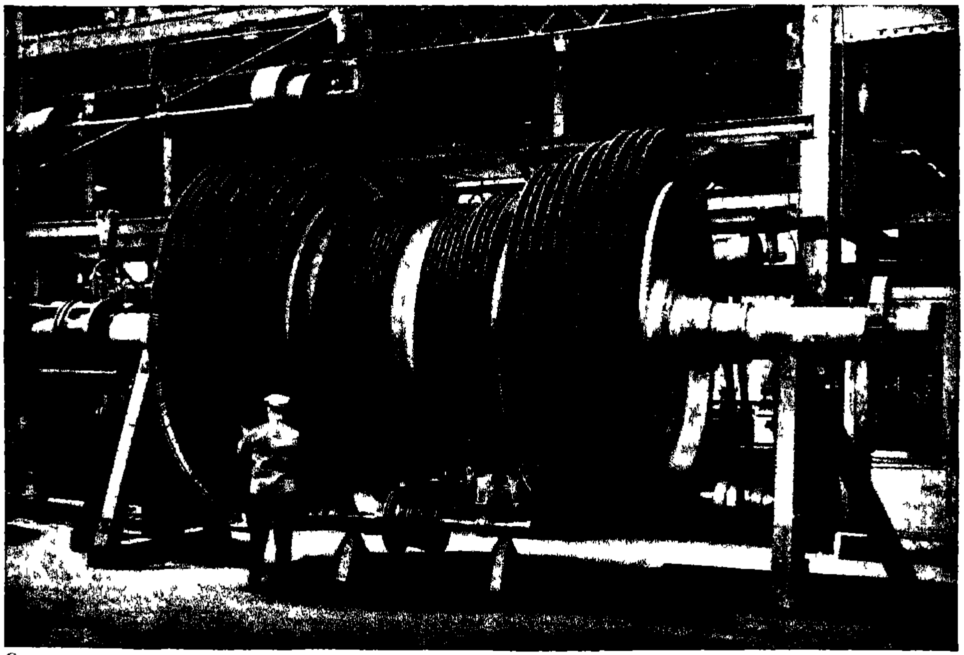
A 35,000 KILOWATT TURBO ALTERNATOR

This single machine generates sufficient electric power to light 700,000 fifty candle power lamps or drive 4000 ten horse power motors

THREE TURBINE UNITS OF 40,000 H. P. EACH



This shows a power house containing three Westinghouse cross compound steam turbines, each developing 30,000 kilowatts. The nearer is the high pressure side of each machine. The steam starts its expansion here, then crosses over and finishes its work in the low pressure side. By having two sides a longer expansion is obtained and more work done. Each side drives a separate generator.



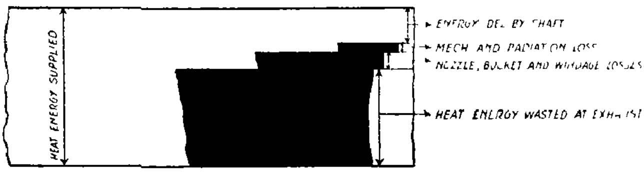
Courtesy of The Westinghouse Electric & Manufacturing Company

This is the rotor of the low pressure side of one of the Westinghouse turbines shown in the upper picture. The thousands of moving blades, their arrangement and shape may be easily seen

types resulting in units of greater economy and size. One example of this is seen in the picture on the preceding page, which shows three turbine units each of which develops 30,000 kilowatts or about 40,000 horse-power.

Much progress has also been made in adapting the turbine to a greater variety of uses. This is due partly to the fact that it has been possible to reduce the speed of the turbine and partly because the speed of the driven machinery such as pumps, dynamos, fans, etc., has been increased by careful attention to design.

One very important type, affecting the economy and output of a power plant, is the low pressure turbine. This is used in connection with large reciprocating engines exhausting at a pressure slightly greater than that of the atmosphere. The steam leaving the engine passes directly to a steam turbine so proportioned that it causes this large volume of steam to expand to a very low pressure and in so doing it develops considerable power, sometimes about as much as the reciprocating engine itself. Thus it may be possible to double the output of a plant without any increase in the quantity of steam used.



THE WORK REALLY DONE BY A STEAM TURBINE

This illustrates diagrammatically the various heat losses in a turbine and the actual energy delivered by the shaft. As this is only about one sixth of the total amount supplied, it is easily seen that the turbine is far from being a perfect energy transformer.

As soon as it became apparent that the steam turbine was to be a successful competitor of the reciprocating engine, the adapting of the turbine to ship propulsion was considered.

The first marine turbine was tried on a small English boat, the *Turbinia*, in 1894, but was not successful. The propeller revolved, but necessarily at a very high rate of speed. The boat, however, only crawled through the water. Experiments to discover the cause of the failure were undertaken by causing a propeller to revolve at different speeds in a tank fitted with glass windows and properly lighted so that observations and photographs could be taken. By this means it was found that when the propeller reached a speed of 1500 revolutions per minute, a kind of cavity was created and the energy of the screw was expended in maintaining this air space, instead of pushing the water away and sending the ship forward. Now if the speed of the turbine was reduced so that the propeller turned in an efficient manner, then the slow speed would cause the turbine to become very wasteful of steam, while if the turbine was run at its proper speed the propeller would revolve entirely too fast.

Sir Charles Parsons, whose turbine is one which is much used for marine work, overcame these difficulties in this way. The *Turbinia* first had a single turbine which drove directly a single propeller of large size. He redesigned and reduced the size of the propeller and instead of one shaft with one large propeller, he had three shafts with three small propellers each. Each shaft was driven by a turbine, but the same steam was used in each of these three machines making them all together act like a triple expansion engine with three cylinders. By dividing up the total expansion of the steam in this way among the three turbines, it was possible to obtain speeds as low as 500 revolutions per minute. In 1897 the *Turbinia* again appeared and made the astonishing speed of $34\frac{1}{2}$ knots per hour. Thus was the problem of turbine-propelled ships solved. The disadvantage of not being able to reverse the direction of rotation of the turbine was overcome by having a separate machine built to turn in the opposite direction, to be used only for the purpose of backing the ship.

While there are many places where the reciprocating engine will never be troubled by the turbine, yet the uses of the latter are continually increasing and its importance in the field of steam engineering is firmly established.

THE THREE GREAT POWERS

The Tremendous Share of the World's Commerce Controlled by the United States, Great Britain and Germany

THE FOUNDATIONS OF INDUSTRIAL SUPREMACY

BEFORE the recent Great War three nations stood out preeminently in the world of trade, the United States, Great Britain, and Germany. Between them they shared an incredibly large proportion of the world's commerce, owned most of the world's ships, smelted most of the world's iron, built most of the world's railways, furnished nearly all the world's heavy machinery, produced the greater part of the world's machine-made articles, and numbered among their citizens most of the world's millionaires.

Germany's position was, of course, adversely affected as a result of the war. Through the Treaty of Versailles she has lost the rich iron deposits of Lorraine and important coal reserves in Upper Silesia. Nevertheless, she is left in a position potentially stronger than that of any other nation, aside from the United States and Great Britain. From the point of view of commercial leadership, she must still be reckoned one of the three great powers.

The people of each of these three preeminent industrial and commercial nations may be pardoned if they attributed the greatness and wealth of their own country entirely to the genius of their race. Few are the people who possess economic training, or who have given any considerable amount of thought to the causes which produce the wealth of some nations and the poverty of others. Very often, indeed, credit is given for commercial or industrial results to causes which are of quite minor importance, while the really important and basic factors are lost sight of.

In reviewing the wealth of the world as a whole, we saw how all-important is the possession of natural stores of energy. Despite the present importance of petroleum and the future possibilities of electric energy developed from water power, the largest source of energy utilized by the industries of the world is supplied by coal. Coal is so heavy and bulky that its transport is costly. For this reason machine industry is chiefly carried on in the countries which have large coal deposits.

If, then, we take a geological map of the world, and ascertain the position of the world's coal areas, we know that we have—at least, if the coal areas are in the possession of white people—an infallible guide to the location of the world's industries. When we turn to such a map and inquire for the great coal-producing nations, we find they are just these three, the United States, Great Britain and Germany.

In its coal possessions the United States is the greatest of these—the greatest in the world. More than half of our forty-eight states contain coal which can be worked on a commercial basis, and this is also true of Alaska. It is probable that the coal-fields of the northern half of the American continent at one time covered the whole of central North America, from the Atlantic to the Rocky Mountains, and from Newfoundland to the Gulf of Mexico. Denudation is supposed to have removed large portions, but what remains constitutes the most magnificent store of natural energy known to the world.

The United States and its wealth of coal beyond the dreams of avarice

First in importance come the mines of Pennsylvania, and this state has always been the first in the production of both anthracite and bituminous coal. The mines of Pennsylvania are part of the great line of coal-fields running with the Appalachian Mountains, and are, perhaps, not merely the richest in America, but the richest in the world. Of anthracite alone the Pennsylvania mines are now equal to producing one hundred million tons a year, in addition to more than one hundred and ninety million tons of bituminous coal. Anthracite of good grade, it may be observed, is found in large quantities only in Pennsylvania and South Wales, but the Pennsylvania fields are by far the more important. This one state of the Union approaches in output the entire production of either Great Britain or Germany.

West Virginia comes next in importance, her mines, as at present developed, being capable of producing one hundred million tons a year. Mining costs are very small, the coal being obtained so easily that the price at the pit-mouth is unusually low. Much of the West Virginia coal goes eastward to tidewater, where it is shipped on barges to eastern seaboard cities and where also it is available for export to other countries. Illinois is third, her mines being capable of producing annually nearly or quite as much as those of West Virginia. The Illinois coal is the most important source of heat and power in the industrial centers of the Middle West. Fourth in order comes Ohio with an annual productive capacity of not much less than fifty million tons.

These four states, Pennsylvania, West Virginia, Illinois, and Ohio, produce more than three-fourths of the entire United States output of coal, but if the mineral wealth of the remaining twenty-four coal states is small relatively, it is great actually.

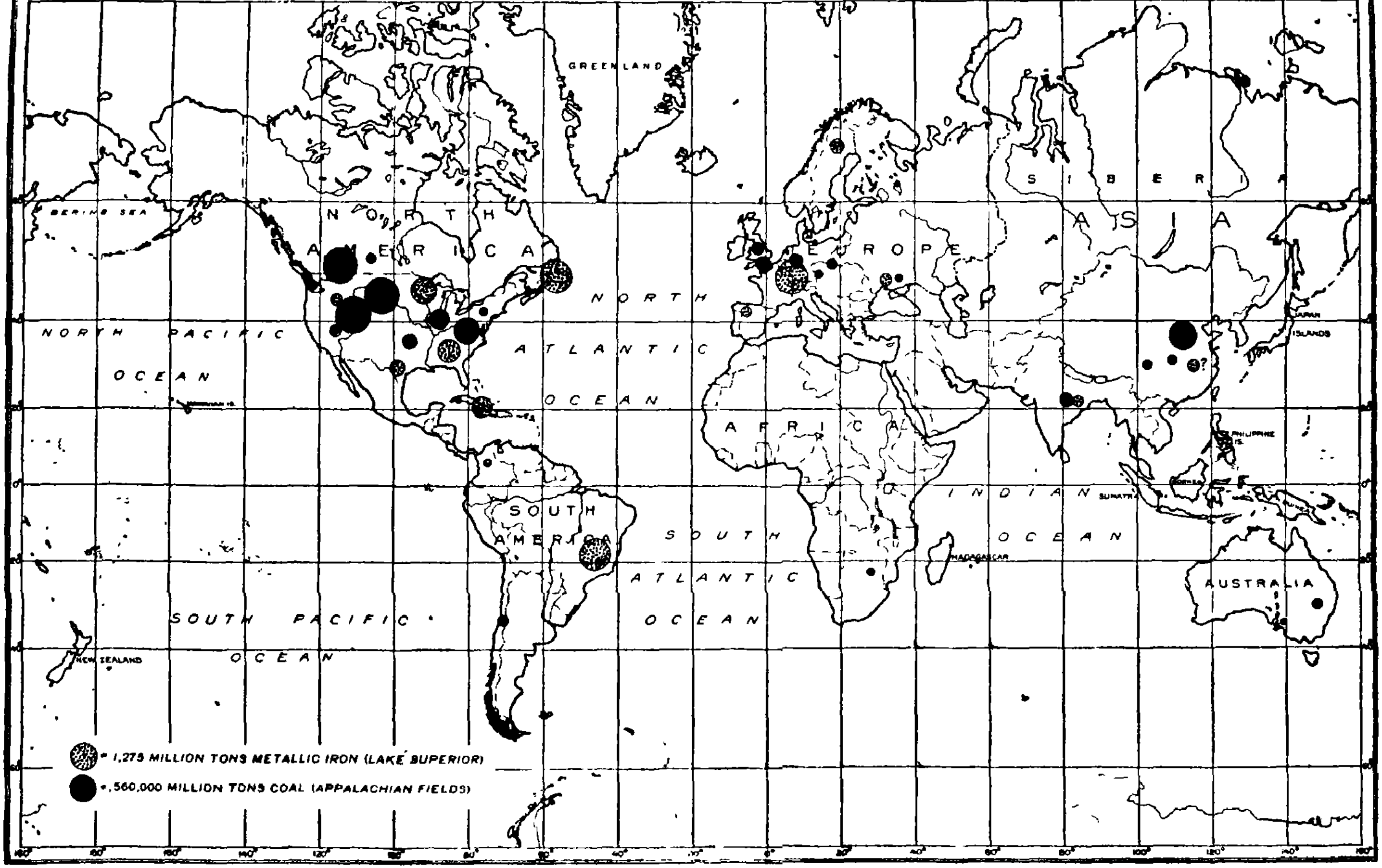
Alabama produces as much coal as all Canada; Indiana more than all Australia; Kentucky as much again as India; Wyoming or Virginia or Tennessee or Iowa or Kansas more than all South Africa; while the remaining states have productions which several coal-less European nations would rejoice to possess.

The United States coal-fields have a total area — exclusive of the Alaskan mines — of nearly three times the area of Great Britain and Ireland. Pennsylvania alone has a coal area as great as that of all the British coal-fields. But this comparison, striking and significant as it is, gives no idea of the superiority of the United States' coal resources. Far-seeing men long ago pointed out to the world the inevitable consequence of the possession of such power. Consider the Pittsburgh coal seam. It consists of a great sheet of coal about six feet thick, fifty miles long, and fifty miles wide.

After sixty years' depletion it is estimated to contain ten billion tons of commercial coal. Still one of the most important considerations is left to state: this wonderful seam of coal is near the surface, and therefore easily and cheaply worked. At many points it is not necessary to sink shafts. Many of the bituminous coal mines of Pennsylvania are quarried rather than mined.

So that the United States has not merely a great coal area, but a rich coal area; and not merely a rich coal area, but a coal area the most available, and therefore yielding the cheapest coal in the world. Given such a natural wealth, even a dull people might become a rich people; and no one has accused the extraordinary medley of enterprising persons of all races which inhabits the United States of either dullness or incapacity.

Germany, the third in importance in the great triumvirate of coal powers, is also exceedingly rich in fuel, but her resources approach more nearly to those of Britain than to those of the United States. The coal wealth of Germany was neither understood nor developed until recent years. So true is this, that while well-informed British writers, basing themselves upon known facts, two generations ago predicted a brilliant future for American industry and trade, the latent powers of Germany were hardly suspected, even denied.



From *The Strategy of Minerals*, D. Appleton & Co

DISTRIBUTION AND RELATIVE SIZE OF THE CHIEF IRON AND COAL RESERVES OF THE WORLD

A German coal-field covering over a thousand square miles

Thus we find even Jevons, the first English economist who understood the coal question, writing in 1865 that "Prussia . . . is incapable of taking any considerable share of the trade of the world." Jevons did not know that Germany possessed in the districts of Upper Silesia, the Ruhr, and the Saar, some of the most important coal-fields of the world.

The chief German coal-field is that of the Ruhr, or of the Lower Rhine and Westphalia. The coal area here is over one thousand square miles in extent. The number of seams is large, and there are more than sixty together representing a sheet of coal fifty to sixty yards thick. This field is estimated to contain 45,000 million tons. Even more wonderful still are the Saarbrücken coal-beds in the Rhine Province, where there are more than two hundred seams one above another, the coal of which, if placed together without the intervening shales and sandstones, would be nearly 400 feet thick. Many of these seams, however, cannot be worked profitably. The other German coal-fields, if not so rich, are also of great importance.

In addition to coal proper, Germany is also rich in lignite, or brown coal. It is only in the last thirty years that German lignite has been worked on an extensive scale. Lignite has not the heating power of coal, and it was only when German enterprise and science discovered how to make the lignite into briquettes, so that it could be economically transported, that it came into extensive industrial use. Three tons of manufactured lignite are equal to about two tons of coal, and even the briquette process would not make the material economical but for the fact that the German lignite seams are so exceedingly rich and so easily worked. Around Cologne, for example, the lignite lies in a seam varying from 60 to 300 feet thick, with only some 30 to 45 feet of matter above it. The lignite can thus be quarried cheaply, and the lignite briquettes sold at so low a price as to make it a competitor of coal in spite of its inferior caloric power.

German coal resources are superior in quantity, if not in situation, to those of Great Britain. The peculiarity of the British coal-fields is that they have been placed by nature very close to tidewater. Germany, whose coal lies so much more inland, is not able to compete with Great Britain on level terms as an exporter of coal for maritime purposes, although she has seriously entered the export market in this respect.

Estimates of the coal reserves of the different countries are subject to an uncertain margin of error. The following estimate, however, is as recent and as authoritative as any:

United States . . .	3,500,000,000,000 tons
Great Britain . . .	190,000,000,000 tons
Germany	400,000,000,000 tons

Since the known coal reserves of the whole world are estimated as only slightly over 7,000,000 million tons, it appears that the United States has about half of the world's coal Add to this the fact that the coal reserves of Canada are estimated at 1,250,000 million tons, and that there is coal in Alaska and Mexico, and it will be seen that two-thirds of the world's coal is contained within the continent of North America. This is the first and most fundamental fact which any one undertaking to prophesy respecting the future industrial leadership of the world and the future distribution of the world's population must take into account. Half of the coal reserves of the United States, like three-fourths of the Canadian reserves, are lignite. But this fact does not materially modify the significance of the figures as given.

Outside the North American continent, the largest coal reserves of the world are probably those of China, estimated to be between 1,000,000 million and 1,500,000 million tons. Some of the Chinese coal-fields are near the coast, and there is no reason why Chinese coal should not at some time become an important article of export. The larger utilization of coal within China itself must wait upon the development of better means of internal transportation.

Aside from the countries which we have already mentioned, New South Wales and Siberia are the only regions in which the coal reserves amount to more than 100,000 million tons.

In these estimates the coal deposits of Upper Silesia have been counted with those of Germany. They account for about one-third of her total, but now have been assigned largely to Poland.

The world's coal output as distinguished from coal possession

When we come to coal production, as distinguished from coal possession, the element of uncertainty disappears. The latent power supplies of the United States and of Germany have been developed so rapidly that the coal production of Great Britain has been altogether out-distanced by that of the United States and approached by that of Germany. The following table gives the figures for 1913, which, as the last year before the war, is more significant than a later year would be as indicating the position that had been attained through the operation of economic and commercial forces alone.

THE WORLD'S COAL OUTPUT: 1913

United States	570,000,000 tons
Great Britain	322,000,000 tons
Germany	306,000,000 tons
Total for the three nations	1,198,000,000 tons
Rest of the world	280,000,000 tons
Total for all the world	1,478,000,000 tons

So far as its importance for industry and commerce is concerned, the quality of coal is very nearly as significant as its quantity. Coal varies greatly in its burning qualities and in its steam-producing powers. Especially important in its relation to the development of the iron and steel industries is the coking quality of coal. There are only a few deposits of coal in the world from which coke of high quality can be made efficiently and cheaply. Here again, it is significant to observe, the United States, Great Britain, and Germany have an advantage over other countries.

Great Britain's especial advantage is found in its possession of high-grade coal immediately adjacent, on the one hand, to important deposits of iron ore, and exceptionally close, on the other hand, to her coast ports. In no other country can coal be brought from the mine to the seaboard and put on board ship so cheaply as in Great Britain. This gave her a great advantage over other countries in the coal export trade. The coal export trade, in turn, has been the most important single factor in the prosperity of the British mercantile marine, and it had a good deal to do with Great Britain's ability to carry and handle other sorts of international commerce effectively. During the Great War, when English ships were needed for other purposes, her coal export trade, especially to Latin America, had to be almost entirely cut off. Since the war Great Britain has been regaining her former position in the coal trade, in part at least, but the recovery of her coal exports has been relatively slow by reason of increased costs of operating her mines.

Since 1900 the yearly output of the world has increased by over 300 million tons, but about 250 million tons of this increase is the share of the three leaders. In view of this overwhelming superiority in the power without which modern machines cannot be run economically, the supremacy of the United States, Great Britain and Germany in industry and commerce is seen to be practically inevitable, given the habitation of the three countries by white men.

In mineral resources other than coal there is also a marked disparity in the position of the three coal powers. Even more than in regard to coal, the United States leads the world in general mineral and metal resources. It is impossible to exaggerate the economic advantages possessed by America and expressed in these fundamental sources of wealth. It is not enough that she has in coal an infallible means of securing other materials even if she did not possess them. She has within her borders the world's best supplies of iron, of copper, of lead, and of that essence of coal, petroleum.

Turning from coal and iron to field and forest, from the clamor and bustle of the industrial center to the peace and quiet of agricultural pursuits, we find the natural advantages of the United States even more strongly emphasized. The United States has been growing so rapidly in population that the world will not long be able to expect from her the large export of grain which America now puts on the market. In the last forty years the home consumption of wheat in the United States has more than doubled. Wheat production has greatly increased, but not at so great a rate, and wheat exports will not continue to be so important as they now are.

But for a wide range of other food crops, notably corn, as well as for live stock, the United States produces much more than she consumes. Despite the fact that the standard of living of her people, the quality and variety of the food consumed per capita, are higher in the United States than in any European country, the United States, unlike the nations of western Europe, produces a *food surplus*.

The magnificent area and range of climate of the United States give her in other respects great economic advantages over her competitors. Great Britain and Germany alike have to look to the United States for their main supplies of cotton. In her forests and fisheries the United States is equally fortunate, and if her forest areas have been too rapidly denuded, she has at last awakened to the necessity of conservation, and drastic steps have been taken to assure the future of her timber supply.

In all of these ways Great Britain and Germany seem alike to be at a disadvantage. In the first quarter of the nineteenth century Great Britain raised more grain than she consumed and exported her surplus. But with the growth of her industry and her commerce, and the consequent increase of her population, she has found it more profitable to devote her energies to other things than agriculture. Not only relatively but absolutely she raises less food than she did a hundred years ago.

Great Britain's unfortunate position in regard to raw materials

In the domain of raw materials Great Britain is even worse furnished than in respect to foods. Very little indeed of British work and industry is done upon purely native materials. But the commercial miracle has become an everyday, unregarded commonplace. Products foreign to her soil and climate or which, if found there, are present in exceedingly limited measure, are everywhere built into her environment. Palace and cottage alike are largely supplied with imported materials.

A very great part of the industrial work of Great Britain is done upon iron and steel. She possesses great supplies of native iron ores. Nevertheless, of her total consumption of iron ore in a normal year, about one-third is imported. More than that, the iron ores which Great Britain imports are much richer in metallic content than the ores mined at home, so that, broadly speaking, about one-half of her production of iron and steel is based upon ores obtained by overseas commerce.

Great Britain has frankly accepted this situation. More than that, she has made of her very limitations the foundations of her commercial policy and power. Producing little of her own raw materials and of her own food, she has become the great commercial *specialist* among nations. By opening her ports freely to the trade of the world, putting her energies into the carrying trade and into the manufacturing and merchandizing of the goods of foreign origin, she has become the world's great commercial entrepôt. There are dangers, of course, in such a policy. To Great Britain more than to any other nation a blockade, involving a complete shutting off of commerce, would mean starvation. Hence her dependence and reliance upon her fine navy. Even before the Great War and the realization of the possibilities of the submarine if used ruthlessly in destroying merchant shipping, Great Britain had come to feel more and more concerned with respect to the dangers involved in her dependence upon the

maintenance of untrammeled national commerce, and upon the absence of commercial discriminations against her by other nations. This disquietude showed itself in various proposals and tentative steps toward organizing the British Empire as a relatively self-sufficient and intradependent economic unit. No single nation, not even the United States, begins to have the magnificent resources of the British Empire taken as a whole. So far, however, the proposals and tentative steps to which we have referred have had little or no visible effect in altering the nature and the direction of the main currents of British trade. Nor is there any likelihood that in the near future Great Britain will find it worth her while to turn her energies more and more into imperial trade at the expense of her enviable position in the general trade of the world. She remains the best single example of a nation whose wealth is built on commerce. Her very life-blood flows through the arteries of commerce.

Germany, unlike England, aimed for economic self-sufficiency

While England has thus deliberately discarded the goal of economic self sufficiency and has built her prosperity upon commerce and industrial specialization, Germany, like most of the countries of continental Europe, has aimed at as large a degree of economic self-sufficiency as circumstances would permit. Nevertheless, she has been able to develop her industries and to increase her population only by accepting some measure of economic dependence upon other countries. The word "dependence" is, in a way, misleading. The dependence of each country upon others means the intradependence of all. Intradependence is merely another name for international economic coöperation. It is through such coöperation, making the wealth of each section available for every other section, that the enormous progress of the last hundred years has been possible.

With Germany, however, economic independence or self-sufficiency was part and parcel of adequate preparedness for war.

Germany, aside from her coal, not richly endowed by nature

Not England's equal on the sea, she tried to lessen her dependence upon the outside world, encouraging her agriculture, for example, by imposing high protective tariff duties upon imported foodstuffs. In the eighties of the last century she was spending from two million to two hundred and fifty million dollars a year on imported food; in the nineties three hundred and fifty to four hundred million. Just before the war this figure had reached the sum of eight hundred million. This, however, was much less than the similar outlay upon the part of Great Britain, whose annual expenditures for foreign food were often as much as a billion and a quarter of dollars.

Germany is not, aside from her coal, richly endowed by nature. Of other minerals, except iron, zinc, and potash, her native supply is small, in most cases insignificant. Her economic progress is for this reason all the more phenomenal. It reflects not merely the energy, industry, and organizing ability of her people, but also the fundamental significance of coal. In Germany's case her supplies of coal have done much toward offsetting other natural disadvantages. Particularly was this true because a large part of her trade is with other west European countries, and many of these are less advantageously placed with respect to supplies of coal than is Germany. Commerce is delicately and sensitively responsive to slight differences in natural advantages.

It was through the skillful use of such advantages as she had, rather than through the presence of such overwhelming advantages as nature has given to the United States, that Germany reached her position as one of the three great commercial nations. Her factories, like those of England, are dependent in very large measure upon imported raw materials. Her population, though in less measure, is dependent upon imports for food. These facts were a source of fundamental weakness in her position in the Great War. Despite the accumulation of vast stores, her sup-

plies of food, of copper, of rubber, and of other things which a country must have if it is to wage war, were inadequate, and it was only by the exercise of marvelous energy and ingenuity that these supplies were eked out, or substitutes found, so that the war could be continued as long as it was. There are no two greater enemies than commerce and war. Not only does war destroy commerce, but commerce, by increasing the intradependence and coöperation of the peoples of the world, makes war more difficult, more expensive, and more hopeless.

War differs from commerce in that both sides lose

Commerce itself involves international competition, and the rivalries thus created are sometimes discussed as though they constituted a sort of "warfare." This is only a superficial aspect of international commerce. We are fond of "dramatizing" the facts of economic life. By emphasizing the competitive side of commerce, the element of international rivalry involved, we dramatize it, or rather, we make it into an exciting game with prizes and victors and losers. The real difference between commerce and war is that both the victors and the defeated lose incalculably by war. They lose in human life and they lose in wealth. In commerce, although some of the rival nations, it must be admitted, gain more than others, *all* are winners. Where war takes toll of life and wealth, commerce multiplies both.

No better illustration of these fundamental truths can be found than the economic relations of the three great commercial nations themselves. America's advance toward national prosperity was not at the expense of Great Britain. Rather the growth of American wealth brought larger markets and new and better sources of supply to Great Britain. In a similar way the rise of Germany has increased the wealth both of Great Britain and the United States. True, these different countries have been rivals for the trade of Latin America and the Far East. But their largest and most lucrative trade has been among themselves. To cite one example, in itself convincing, Germany before the war sold more goods to England than she did to any other country; she bought more goods from the United States than she did from any other country. Great Britain, also, bought more goods from the United States than from any other country, and the United States was also her largest and most profitable market, aside from British India and Australia. And both as a market for British goods and as a source of supply for British imports, Germany stood next to the United States. Turning to the statistics of American trade, we find a similar situation. The United States bought more goods from Great Britain than from any other country, but, on the other hand, the United States sold more goods to Great Britain than to any other country. As a market for the products of the United States, Canada stood second to Great Britain, but Germany was the third largest of our markets and she was the second largest of our sources of supply. The trade rivalries of these three great countries were in fact of relatively little significance as compared with the benefit each one of them derived from the trade of the other two.

These facts appear clearly in the following table which shows, in millions of dollars, the annual trade of these three great commercial nations just before the war. The pre-war figures are more instructive for our present purposes than more recent statistics would be. In interpreting their significance it is important to note that the aggregate trade of these three great countries constituted one-third of the total trade of the world and that a very large proportion of their trade was with each other.

POSITION OF THREE LEADING COMMERCIAL NATIONS IN THE WORLD'S TRADE

(Figures are in millions of dollars)

Source of Exports	Destination of Exports				
	United States	Great Britain	Germany	Other Countries	Total
United States		650	425	1,375	2,450
Great Britain	290		260	2,000	2,550
Germany	180	380		1,865	2,425
Other Countries	1,330	2,270	1,915	8,410	13,925
Total	1,800	3,300	2,600	13,650	21,350

THE WORLD'S BLACK DIAMONDS

The Great Traffic in the Sunshine of the Ancient World upon which Modern Industry is Based

COAL, THE BURIED TREASURE OF NATIONS

THE sensational impetus felt by industry and commerce during the last century, an impetus unparalleled in the history of the world, had its origin in new applications of force through the use of machinery. The three principal factors in that epoch-making development have been the perfecting of steel as the prime material for machinery; the working of coal to provide power in the form of heat; and the unexampled response from human invention, as these new instruments of progress came gradually into play.

We have pictured the part taken in this great practical drama by the master-material steel, and we must now show how coal, scarcely known two hundred years ago as one of the world's supreme sources of energy and wealth, has contributed to the industrial revolution, and has placed three nations — the United States, Great Britain, and Germany — far ahead of the rest of the world, in positions that make conquests by arms appear local and paltry.

Doubtless a time will come when the use of coal for power-producing purposes, through its transformation into heat, will be superseded. The earth has greater reservoirs of power than all its accessible coal-beds, and the needs of mankind will stimulate invention till these reservoirs are utilized. For the moment, however, coal reigns supreme, as it has reigned for nearly a hundred years, and will reign perhaps for another hundred years. In the main, it provides the strength that moves the world's machinery, as steel provides the material for that machinery. Even when electricity supplies the immediate working power, coal usually takes its part, a stage farther back, in the production of that electricity.

This, too, will doubtless some day be altered; but when coal is no longer the chief agent in the production of power, either in the form of heat or of electricity, an enormous range of uses will remain for its chemical transformations, and this giant, now grimy and evil-smelling, will come to be regarded as a fairy magician, whose wand calls forth all the colors, scents, and essences of a cleaner life.

What is coal? The answer is not so simple as the casual observer would expect. We know that coal is "buried sunshine" — the fossil of enormous fern-trees which drank in the sunlight pouring down upon the prehistoric world, and now gives the sunshine back to us in the form of fire, but that is not enough. Large sums of money have been spent at law without a conclusive definition being arrived at, for the word "coal" covers a wide variety of earth-held substances that may be used as fuel. It has no standard chemical composition. Coal is a rock, composed chiefly of carbon, and formed from vegetable matter, capable of being burned as a fuel, and when so burned producing, in varying degrees, heat and light.

The varying composition of coal depends partly on what it was formed of — that is, the nature of its vegetable basis; and partly on where and how it was formed — that is, on such conditions as place, time, pressure, and the influences of heat and of chemical change. This great variety in composition enables coal to be put to a wide range of uses, one kind being best for one purpose and another for another purpose, and excellence in quality is not absolute, but comparative, according to the particular use for which it is intended.

Broad classifications of the different sorts of coal depend chiefly on the proportion of carbon each contains. Thus, fuels may be arranged by their carbon-wealth in the following ascending scale: wood, 50 per cent of carbon; peat, 52 to 60 per cent; lignite and brown coal, from 55 to 65 per cent; cannel coal, from 75 to 80 per cent; soft or bituminous coal, from 65 to 85 per cent; anthracite, from 75 to 95 per cent. Above this the substance becomes graphite, or almost pure carbon, and is unburnable. These different kinds of coal, with from 60 to 95 per cent of carbon, are graded imperceptibly into each other by the conditions under which they have been formed, the central group of the series being the bituminous or so-called "soft coals," of which Pittsburgh coal is typical.

The substances in the earth that go to make up the coal

Besides carbon, coal contains hydrogen, oxygen, nitrogen, sulphur, and other constituents in small proportions — the hydrogen, oxygen, and nitrogen decreasing as the carbon increases, while the other ingredients make up the ash of the coal. When the latter consists of an easily fusible mixture of materials, clinkers forms as the coal burns.

Of course, naturally, one seam or bed does not show at once all these different fuels, such as peat, lignite, bituminous and anthracite, but a gradation may be noted over large regions. In Montana, for instance, the coals of the eastern part of the state, where the rocks are flat, are lignitic, but in the western part, where the rocks are bent up into the Rocky Mountains, the coals are of bituminous nature. In western Pennsylvania the coals have not been subjected to a sufficient extent to the heat and pressure that develop when the crust of the earth shrivels to form any higher grade than bituminous. In northeastern Pennsylvania the rocks have been markedly folded, the resulting heat and pressure have driven off some of the gases from the bituminous coal, and the same rocks that contain the latter in western Pennsylvania are found to contain anthracite.

The qualities of the various kinds of coal found in the world

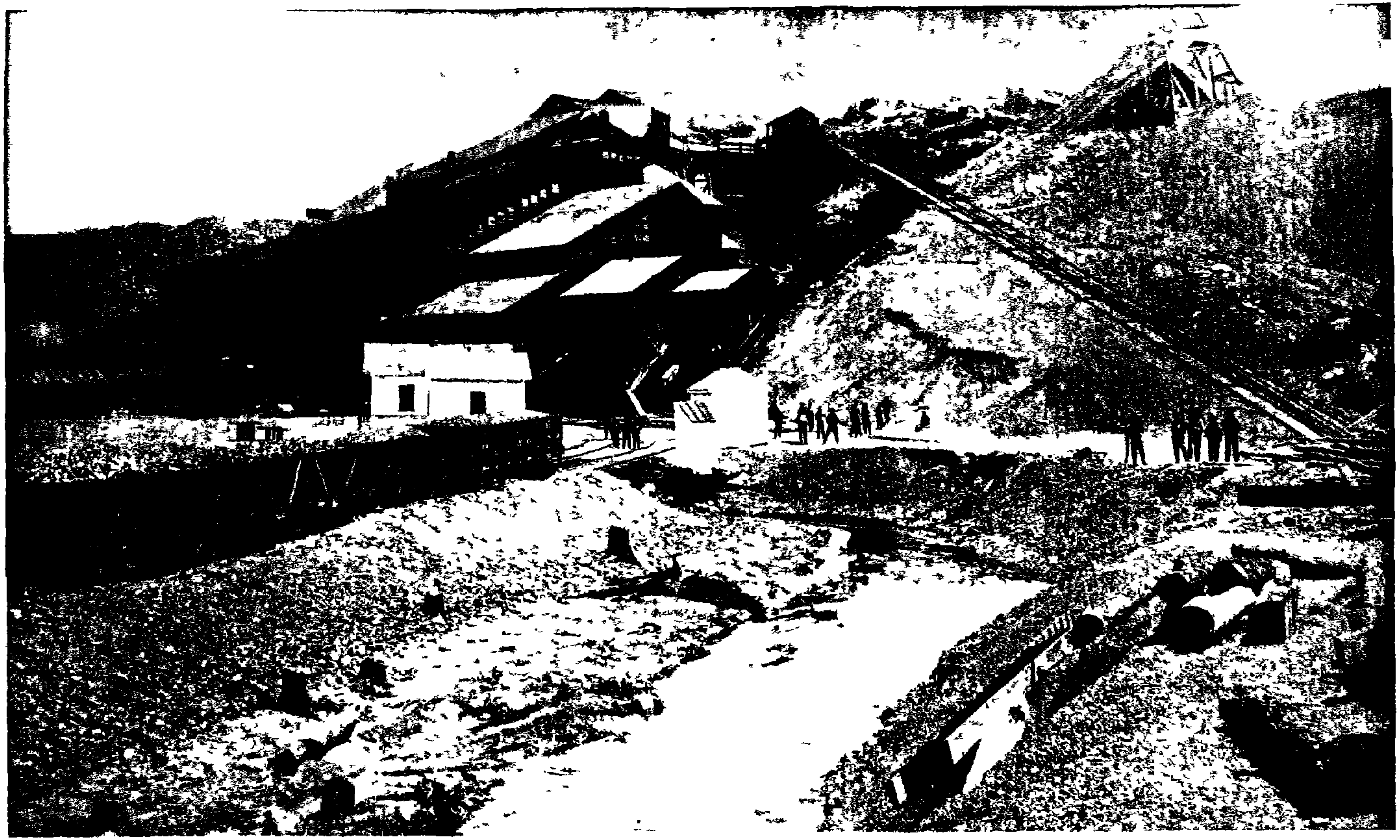
It is necessary to take a survey of the coal veins of the world, and to imagine varying types of vegetation laid down under differing conditions, subject to greater or less stresses, and to incidental rather than universal chemical reactions, if we are to classify truly the various kinds of coal.

Lignites are found in considerable quantities in the western and southern parts of the United States, especially in the Gulf States, North and South Dakota, Montana, and Washington. Cannel coal is so called because it flames into a torch like a candle. It is bright and smooth, sometimes crackles and splits, produces paraffin, and is excellent for gas-making. Often it occurs in conjunction with bituminous coal. Soft or bituminous coal varies widely in its composition, grading into brown coal on the one hand, and into anthracite or hard coal on the other hand. It is the most generally usable variety for steam, gas, and coke-making purposes. The name "bituminous" was given to it because it sometimes "runs," and has a bituminous appearance, though there is no bitumen in it. It lights readily, whereas anthracite is difficult to light, though giving great heat when started. Anthracite contains so little volatile matter as to be almost smokeless. It is the hardest of the fuels and the most shiny. It breaks with uneven, rounded surfaces which so much resemble the surfaces of some shells that the coal is said to have a "conchoidal fracture."

How coal is found distributed irregularly throughout the world

The earth's coal-beds — laid down with a marvelous regularity in level strata, almost unmixed with casual intrusions of other matter, though the seams, varying in thickness from less than an inch to sixty feet, are much broken by "faults" where they have snapped and dropped — are found associated with, and surrounded by, beds of sandstone, shale, and limestone. Nowhere are they the dominant rocks.

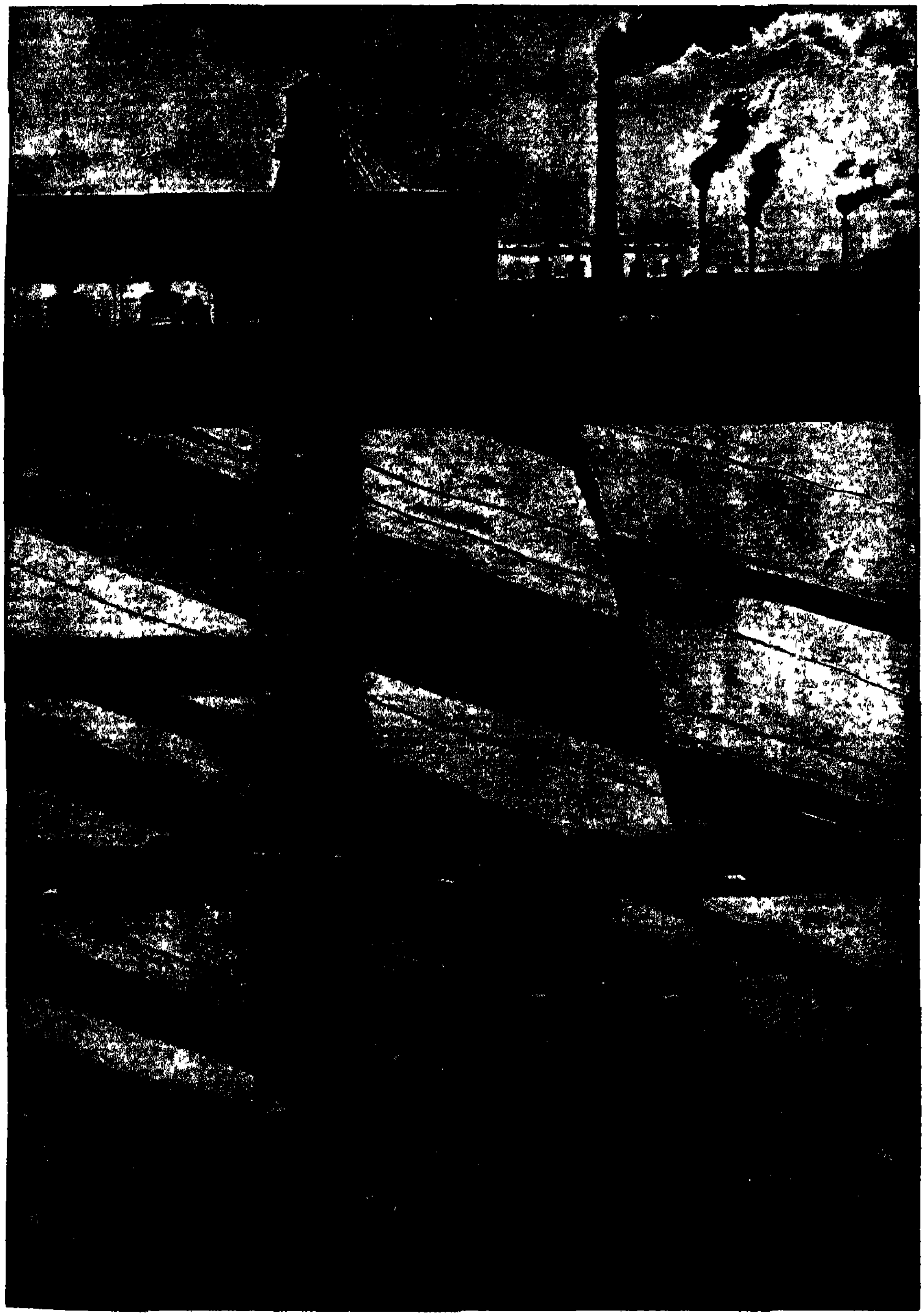
A COAL MINE AND "BREAKER" IN THE PENNSYLVANIA COAL REGION



Courtesy of Prof H Ries Cornell University

Anthracite coal on its arrival at the surface is put through powerful crushers which break it up into small pieces which are then passed through revolving screens which sort it into the various commercial sizes known as stove, chestnut, pea, buckwheat, etc

Here is a picture diagram of a coal mine "with the lid off," showing what the pits and workings are really like The black slanting lines mark the coal seams, and roadways lead to these from the shafts A constant circulation of pure air is maintained underground, either by a furnace at the bottom of one shaft, causing warm air to rise, or by a pump at the top, which sucks the bad air out of the



mine through the special ventilating shaft A quarter of a million cubic feet of air pass through the shafts of some mines every minute A single pair of shafts will serve thousands of acres of workings. Sometimes an underground passage is a mile long, and one mine in England has fifty miles of passages — fifty miles of walks, that is, through prehistoric forests which once were green in the days of long ago.

The so-called "carboniferous" system, one of the geological ages into which the earth's history is divided, is a huge belt of the earth's crust streaked here and there with comparatively slender layers of coal. For example, the richest coal measures in Great Britain, those of South Wales, are 8000 feet in thickness, and the aggregate of the many coal seams running through them is only 200 feet, or one-fortieth of the whole. This is an instance of richness, but coal in some of its forms is found, in traces, from its formation going on today in lakes, estuaries, swamps, and bogs, down to the Silurian period, which marks, in the far-off past, the margin of its recognizable existence.

Coal is distributed throughout all the continents, but with much irregularity, as is shown in a later chapter, where, also, the table on page 547 gives the amount each country contributes to the world's production of about fifteen hundred million tons per year.

The source of modern power of which the ancient world knew nothing

This enormous output of coal, near all the busy industrial centers of the world, to run mankind's machinery, and the trains and the ships that exchange the productions of every race and climate, is quite a new thing. The ancient world did not know of coal, and had no practical use for it. About 2000 years ago the Britons knew the use of coal, and the Romans learned it from them. The Anglo-Saxons used coal for domestic purposes, and England appears to be the first country in which it is unmistakably mentioned in writing, the "Saxon Chronicle" being the recording manuscript. England, too, holds the historical record for beginning the working of the mineral — a charter granted in 1259, by Henry III, to the inhabitants of Newcastle to dig coal in their Castle fields. But for hundreds of years after that the use of coal was regarded — in London, at any rate — as a superfluity, an offense, and a danger to the public health, to be prohibited when Parliament was sitting, and taxed at all times.

The gradual rise of the modern age of coal power

The explanation is that there is no need of coal in a country living a simple life, with plenty of wood near at hand, and no large cities. Why should men undergo the toil and danger of digging coal from the dark depths of the earth when with less labor they can fell a tree? It was only when the forests were being used up and the great cities were growing that necessity forced men to face recurring calamity and to battle with the ill-understood dangers of the mine — a battle that has been fought steadily ever since, with accumulating difficulties and a growing list of triumphs.

It was the extension of London that made the trade in coal imperative, and by 1605 four hundred ships of small tonnage were engaged in bringing coal from the mines. The tax on coal, which had been a prolific source of revenue under the Stuarts, was remitted in the reign of William III. From the middle of the eighteenth century the consumption of coal rapidly increased owing to the use of coke, instead of charcoal, for smelting; and the advent of steam as the power for driving engines, stationary and locomotive, with the use of gas as an illuminant. In America the coal beds near Richmond, Va., were discovered in 1701, and mining was begun in 1750. Anthracite was first used in 1793. Extensive coal mining did not really begin, however, until about 1820.

Coal, which had lain unappreciated as a dormant resource through countless centuries, began to be a half-banned luxury about three hundred years ago, became a growing necessity two hundred years ago, was realized one of the master-materials of the world's progress a hundred years ago, and now is engaging far-seeing minds in anxious speculation as to its probable duration under the inexorable demands of mechanical industry. It seems as if its swift and furious race might be quickly run in some countries, judged in the perspective of historical ages; but however that may be, its conquest will remain a most notable chapter of human endeavor.

THE MEN WHO GO DOWN INTO THE EARTH

Nearly a thousand miners have here received their safety lamps, and are just going to the shaft to descend into the mine. There are in the United States over seven hundred thousand miners and they can get out from two to four tons of coal per man per day.

The stern fight between men and death in the mine

Today we accept as a matter of course the smooth running of the stupendous coal mining operations of our land, except when a blast from the mouth of Death quenches all the life of a mine and devastates the homes of the miners. Then we sigh, and accept the calamity as a sad recurring certainty. But we do not realize how long and stern the fight with Death in the mine has been; how great, if slow, the victories of human ingenuity.

The history of the getting of coal is a history of its difficulties overcome; and there is no more impressive record of the task of understanding nature and bringing about an accommodation between her laws and the life of man. For, in getting coal, men entered gradually a new sphere of work — the solid crust of the earth — with dangers accumulating at every advance, and each fresh lesson was learned through ruin and loss of life.

At first coal was quarried, so to speak, horizontally, in a cave-like manner, where it cropped out on the surface, the seam being followed as if through a broad, dipping tunnel. In those times, women were employed to carry the coal to the outlet on their backs in baskets. The first difficulty encountered was the presence of water, which, through the dip of the strata, accumulated in the workings. When vertical shafts became necessary to reach the lower and more valuable seams, this difficulty was increased, as water-bearing layers were bound to be struck, and the water collected in the bottom of the shaft.

At first, pumping was introduced by means of a chain of buckets worked by a water-wheel, and then by a windlass turned by horses, but many mines were captured by the waters, and for the moment man was driven back defeated. The tables were turned, however, in 1705, when Thomas Newcomen invented the atmospheric steam engine, pumping through air pressure, which, by 1712, had reached such a state of efficiency that it had begun to master the waters of the flooded mines, and enable shafts to be sunk to deeper levels.

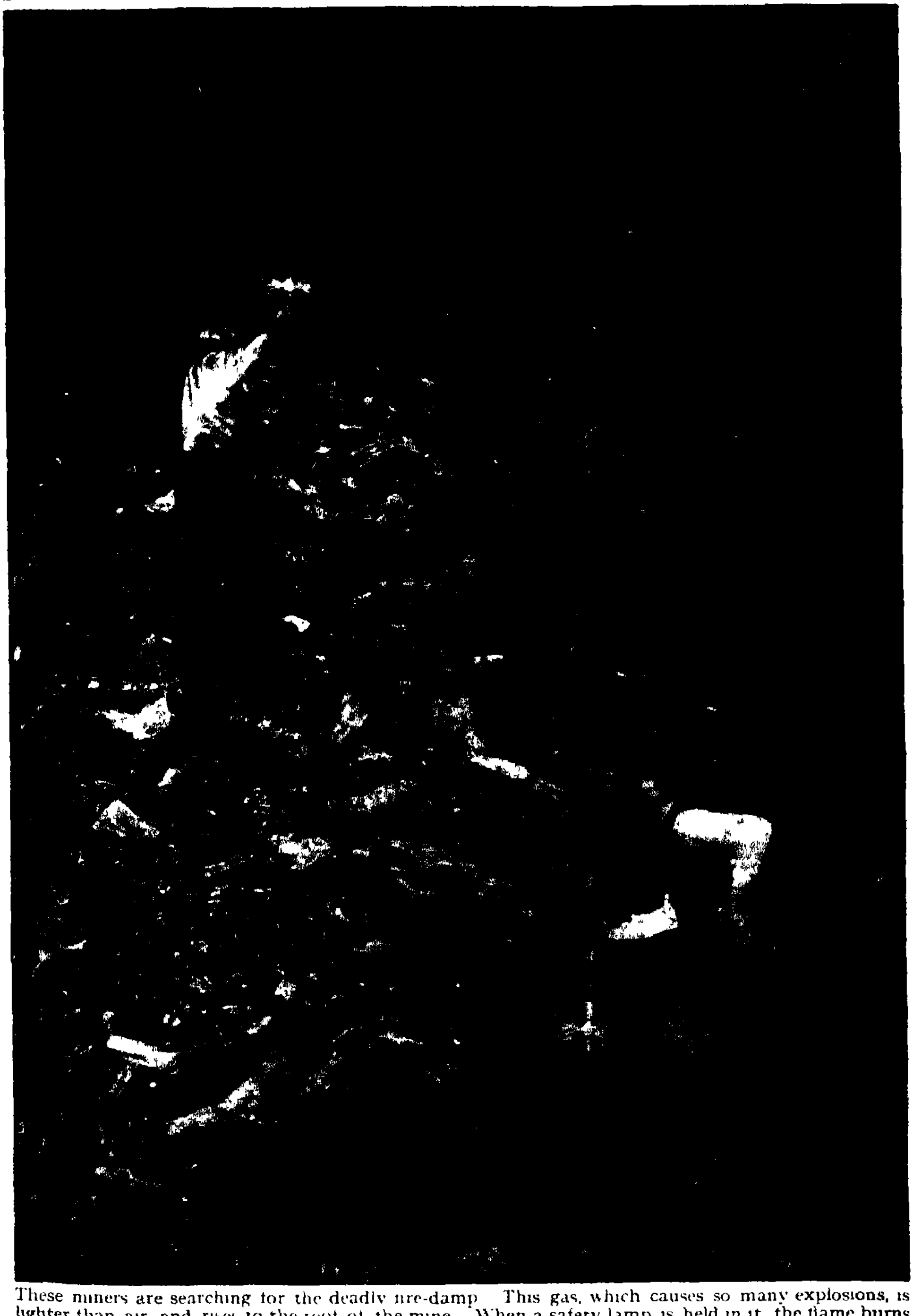
The deadly foe in the mine which science has even yet not overcome

But the deepening of the mines revealed a new danger. Hitherto, water had been the enemy. So plentiful was it in some districts that it produced a quicksand layer through which sinking was impossible, until the soil below and around the bottom of the shaft had been frozen solid to facilitate its removal, after which the orifice was cased with rings of iron tubing. When the mines, however, had passed through the region of damp, and reached a dryer layer, they encountered a far deadlier foe, that even yet has not been finally overcome. They were met by fire, and were temporarily routed. The first recorded explosion occurred in 1705, and three years later another explosion cost 69 lives. Increasing depth further complicated the problem of ventilation, for, below 50 feet, where atmospheric changes of temperature cease to produce any effect, there is an increase of one degree in temperature for every 60 feet.

With the increase of gases, difficulties of lighting, while work was carried on, were accentuated, and the greater depths of shafts and extent of workings made imperative a change in methods of hauling coal to the bottom of the shaft and raising it to the top. All these difficulties came thronging on the mine managers at once, as soon as coal had been followed towards the hot darkness of the earth's core.

While mines were of inconsiderable depth — no deeper than many wells of today — gases, of course, collected, though in small quantities, and it became customary to explode them before the miners entered the workings. For this purpose, a "fireman," as he was called, wrapped in fire-resisting blanketing saturated with water, crept forward and caused an explosion by projecting a candle at the end of a long pole. He then flung himself on the ground while the flames passed over him under the roof. This could not last long, and the next step was to tap the gas where a strong escape was found, and pipe it to the surface — an invention of Carlisle Spedding.

SEARCHING FOR THE MINER'S DEADLY FOE



These miners are searching for the deadly fire-damp This gas, which causes so many explosions, is lighter than air, and rises to the roof of the mine When a safety lamp is held in it, the flame burns blue, and the miner can detect it and take precautions. It escapes from the coal, often with a hissing sound, when the workings tap the cavities in which it is held.

His son James made a great step towards safety by so arranging the ventilation that the air, in passing from the downcast shaft to the upcast shaft — two shafts being now sunk for each mine — swept through all the workings, and so tended to clear away the gases, instead of being directed only to the part of the mine where the men were working.

The demand for coal that first led to the invention of railroads

The demand for coal continuing to increase enormously, the workings, which for a long time had not been carried more than two hundred yards away from the bottom of the shaft, were extended, and sinking to lower beds went on constantly, bringing in the necessity for quicker haulage of the coal through the mine to the bottom of the shaft, and more effective lifting to the surface. The haulage difficulty led to the invention of railroads, consisting of wooden rails along the main tunnels of the mine where horses could draw wheeled tubs. These "rail" roads were also used for conveying the coal in the north of England from the head of the shaft to the waterways for distant transport.

The lifting of the coal up the shaft was first managed by horses working a windlass. When steam was employed for this purpose, it was employed indirectly. Newcomen's engine, or James Watt's improvement of it, was used to raise water, which in its turn worked a water-wheel to raise the coal, a system ended by Watt's later improvements on the steam-engine making it directly usable for lifting loads up the shaft.

The speed of coal-getting was now enormously increased. At first, wicker baskets were suspended in the shaft from hempen ropes, and it was thought wonderful that 90 tons of coal should be raised in a day from a shallow Newcastle mine. Three hundred tons a day was the largest amount that was ever raised by this primitive system of winding. Now, as many thousand tons may be raised in a day by powerful steam or electric hoists, the latter sometimes working automatically.

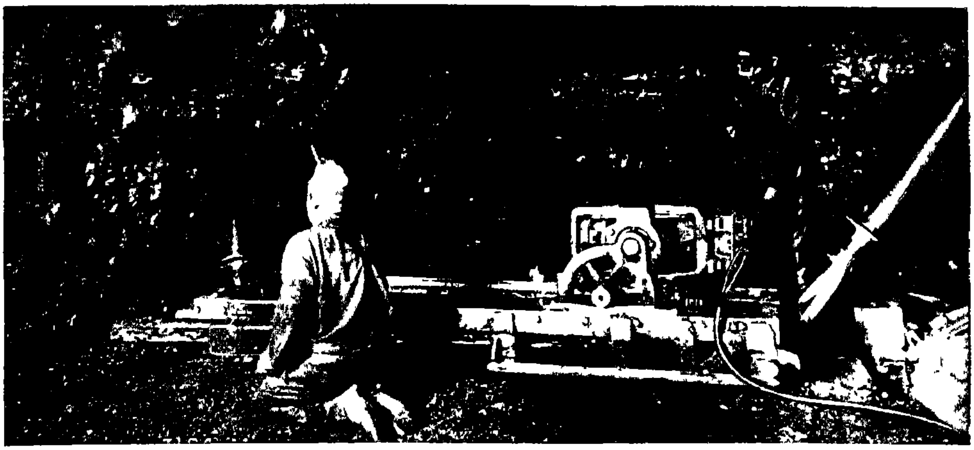
How the coal came up the shaft in the olden days

An early impetus to the swift removal of coal from the mine was given by John Curr, of Sheffield, who substituted cast-iron rails for wooden ones, wheeled cars for the old baskets, guides in the shaft to carry steadily a firm cage, and a flat rope that increased the diameter of the drum on which it was wound as the cage neared the top, and thus quickened the pace of ascent. He also was the first to use fixed engines for hauling coal cars. It may be said that Curr's improvements in the last quarter of the eighteenth century, and the advancements on them by Hall, an English engineer, in the first quarter of the nineteenth century, established broadly the system now in force for raising the coal from the mine, though, of course, improvements have been constantly introduced, with labor-saving arrangements, at every point in the process.

While these measures for insuring swiftness and economy were being taken, the fight for life in the ever deepening pits went on. Diluting the escaping gases with a strong ventilating current, and firing small accumulations, proved utterly insufficient to prevent terrible catastrophes; while the steel-mill light, a flint-and-steel revolving machine that gave forth sufficient light to work by in places where candles would have fired the gas, which had been regarded as safe in quite shallow mines, proved fatal under differing circumstances. At the beginning of the nineteenth century seven terrible explosions occurred in a few months, and public discussion respecting systems of ventilation became eager.

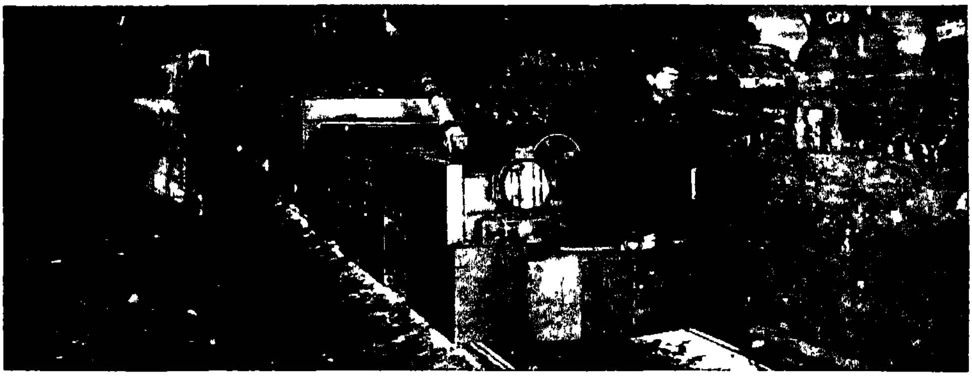
It was clear that the dilution of escaped gases by a current of fresh air was not an adequate remedy, for gases constantly accumulated in foulness till they fired when passing over the furnace at the bottom of the upcast shaft. Great improvements were made in ventilation, particularly by John Buddle, of the Wallsend Colliery, at Newcastle, who introduced the compound system, supplying two streams of fresh air instead of one, and limiting the circuit made by each current.

MODERN METHODS IN COAL MINING

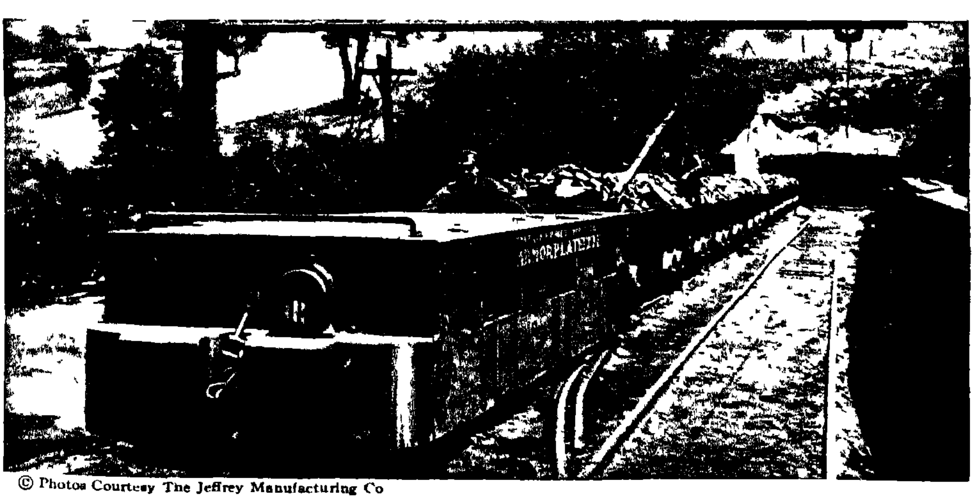


UNDERCUTTING THE COAL

The chain with sharp teeth shown at the left cuts a groove so that the coal may easily be wedged off towards this undercut by means of a little explosive. Grooves were formerly cut by hand, the miners lying on their sides beneath the mass—a position both inconvenient and extremely perilous



TEN TON "ARMORPLATE" TYPE ELECTRIC LOCOMOTIVE HAULING COAL IN A MINE



© Photos Courtesy The Jeffrey Manufacturing Co

TRAIN OF COAL CARS EMERGING FROM A MINE AND ON ITS WAY TO THE BREAKERS

How Sir Humphry Davy gave the miner's safety lamp to the world

In spite of these precautions, accidents continued, and it became clear that relief must be sought through preventing the ignition of the gases, as they themselves could not be entirely cleared away. Under these circumstances, Sir Humphry Davy was asked for his advice, and paid a visit to the north of England, where the facts were placed before him by Mr. Buddle — the most competent colliery manager of his day. "I think I can do something for you," were the modest words with which Sir Humphry closed the interview, and seven weeks later he announced that his experiments had been fortunate beyond his expectations. The result was the discovery of the Davy safety lamp. "We have at last subdued the monster!" was the exclamation of Mr. Buddle when he saw the lamp burning amid gases which it did not fire. Later, when asked why he had not patented his invention, Sir Humphry replied: "I never thought of such a thing. My object was to serve humanity." It was a noble ending for a great crusade, and affords a good illustration of the humanitarian results of many of this scientist's researches.

The lamp that has saved thousands and thousands of lives

Davy's lamp is based on the assumption that an explosion will not pass through small apertures, and accordingly he made a wire gauze lamp. It has been found that the gauze must not contain less than 784 apertures to the square inch. Though the invention has been the means of preserving tens of thousands of endangered lives, and cases of apparent failure have often been referable to gross ignorance or willful carelessness on the part of the users of the lamp, it has been ascertained that immunity from explosion depends on the velocity with which a current of bad air impinges on the gauze. Shields are made to ward off the air rush, and other improvements have been made, but to Davy belongs the lasting credit of the original invention of this great safeguard.

The man who works day by day with Death at his elbow

The work of the miner ever has been, and always will be, a warfare with danger. Death lurks at his elbow. He may be poisoned by black-damp (carbonic acid), or white-damp (carbon monoxide), or fire-damp, also called marsh gas (light carbureted hydrogen), or after-damp (the products that creep through a mine after an explosion); he may be crushed by falls of the roof or of coal, for always the weight of the superincumbent earth is tending to bring down whatever is overhead, and to close up the open roads by pressure on all sides, "creeping," as it is called.

Indeed, all his work below is carried on in the midst of forces which, whether he is alert or not, may trap and maim him. In the United States between 700,000 and 800,000 men work in coal mines, of whom about three-quarters are engaged in the production of bituminous and lignite, and one-quarter in that of anthracite coal. Every year there are over 2000 fatal accidents, with the proportion between the accidents in anthracite and soft coal mines the same as the relative distribution of men. The greatest loss of life is due to the falling of roof and coal, explosions coming next in number of fatalities.

But science is continually working to eliminate the dangers of coal mining. It was formerly believed that fire-damp was the only cause of large explosions, and coal dust was entirely ignored. After a time, however, the suspicion arose that certain mysterious disasters might be due to explosions of this dust, and science stepped in to settle the question. Many experiments were made, notably by the United States Bureau of Mines. This institution built a large chamber in which clouds of coal dust could be stirred up, and the sparks from trolleys or flames of shots could be imitated. It was found that dust could explode, very decidedly, and means were at once taken to prevent accidents from that cause. Dust was sprayed with water in the mine, or kept down by covering with rock dust, and many lives have thus been saved.

DUMPED AND ON ITS WAY TO A PORT

Photo Press Illustrating Service N Y

The loaded car carrying $2\frac{1}{2}$ tons of coal is run on to the rotary dump, automatically clamped and unloaded by completely revolving The dump has a capacity of four cars per minute

© Ewing Galloway, N Y.

Long trains of loaded coal cars on their way to ocean shipment or city consumption, as seen in the Baltimore & Ohio yards at Baltimore.

The first thing to be done when coal is discovered

Before a shaft is sunk, experimental boring is started on a site suggested by geological knowledge. The placing of the shaft is most important, for it should provide, if possible, for at the very least three conditions — the working of the seam of coal from its lowest point, so that the gradients in the main roads of the mine may fall to the bottom of the shaft and help drainage and haulage; the working of the coal owned from its center, to prevent unnecessary length of underground ways; and the convenient removal of the product from the mine to the consumer. Shafts are sometimes circular, as those of that shape best resist pressure, but rectangular shafts are more common. It is not customary to sink the principal shaft first, but to regard the ventilating shaft as experimental. The cost of sinking depends on the hardness and slope of the strata, and the amount of water, running sand with much water being more difficult than harder layers. The shaft is often lined with planks on a framework of timber, or with reinforced concrete, sheet-iron or brick. On reaching the seam main tunnels are driven into the coal, at least two being started at once, and connected as they proceed, to facilitate ventilation. Near the bottom of the shaft is excavated the stabling for the horses, ventilation being more easy there. The shaft itself is continued below the level of the workings, the covered terminal part, or "sump," being used to receive drainage.

Propping up the earth with steel in the underground roads

A considerable part of the expense of mining is incurred in timbering the roadways and workings, which are always subject to falls, and are artificially kept open. Steel is now used more and more instead of wood for the support of the roof, especially where pressures are heavy, and the change is an economy, for whereas steel is more than twice as expensive as wood, its life under the stresses of the mine is six times as great as that of wood.

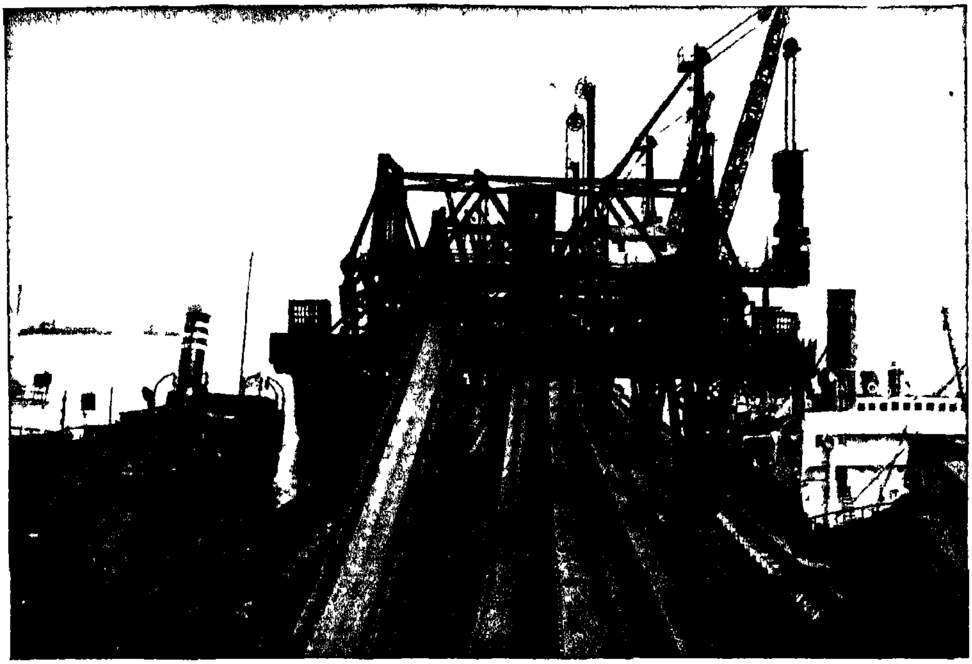
The derricks, or "head-frames," above the shaft, formerly of wood, are now more frequently made of steel. The mouth of the shaft is strongly reinforced. The rope almost invariably is of steel wire, either flat or round, and is expected to raise ten times its customary load without breaking. This sometimes reaches four tons of coal, besides the cage and rope. Operations of such extent demand larger shafts, more elaborate in construction than heretofore. One shaft in Pennsylvania measures 12 feet by 52 feet, with a depth of more than 1000 feet, and is divided into separate compartments for hoisting, pumping, and ventilation. A few collieries abroad are more than 3000 feet deep. In addition, many mines can be entered by tunnels. These run slightly uphill into the mine, the resultant grade favoring the loaded cars as they come to the surface, and allowing the water in the mine to run out by gravity.

Haulage in the mines is now generally by mechanical means along the main roads, and by horses or mules between the workings and the main roads. Electricity is often employed for lighting purposes near the bottom of the shaft, but not near the workings, as they are constantly being moved back as the coal is taken out.

The various ways in which the coal is got out of its solid bed

The systems of getting the coal from its solid bed differ in various localities and countries. Near the bottom of the shaft much of it is left to prevent subsidence. The two most general methods are by chamber and pillar workings, removing the coal in rectangular blocks, and by long-wall working in which the whole face of the seam is attacked and removed. As the coal is removed, the roof being propped up in the workings, the refuse is thrown back, or is built up, according to its character, behind the workers, into the waste open space, "goaf" or "gob," where the coal seam was, and the remaining space gradually closes in owing to the earth's superincumbent and surrounding pressures after the timbers are removed, and the working stalls along the face of the seam have been further advanced.

LOADING SHIPS BY BELT AND BY CAR LOTS



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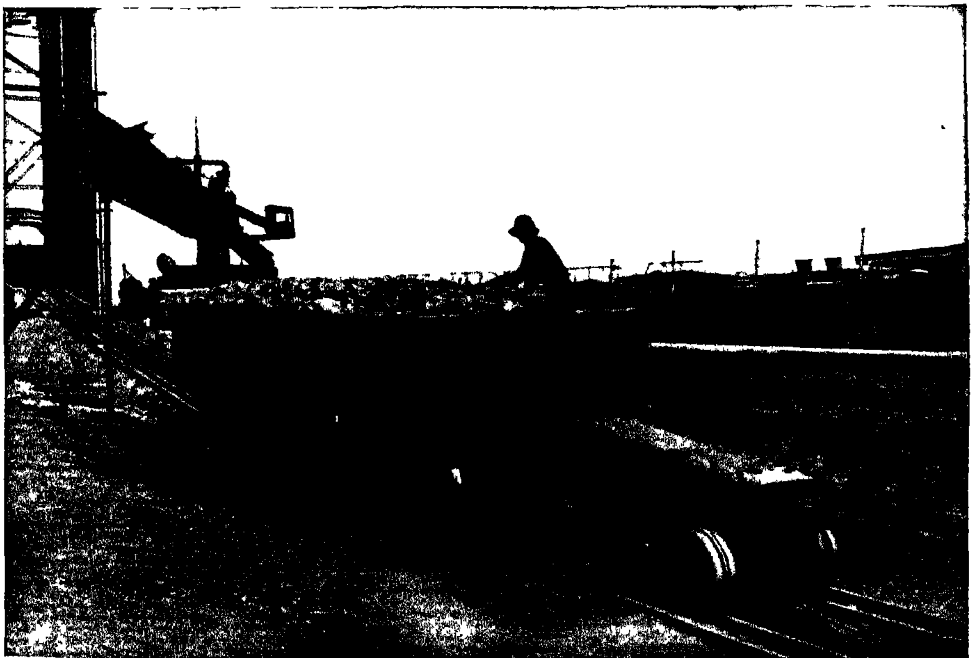
These belt conveyors carry the coal out to the bucket cranes which pick it up and drop it into the ship's hatchways. These vessels are loading at the Baltimore & Ohio piers in Baltimore



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Hocking Valley Railroad Co.'s coal docks at Toledo, Ohio. The car is pulled up by an electrically operated cable to the platform and hoist

The actual quarrying of the coal is managed in various ways, but usually by coal-cutting machines, which cut a groove in the bottom of the coal vein, or in the underlying rock. Grooves were formerly cut by hand, and while doing the work the miner lay on his side, wielding a pick till the length of the face allotted to him was undercut as far as he could reach. Holes for shots are then drilled in the coal face above the undercut part, and charged with an explosive, and the firing brings down the wall of coal as far back as the holing has allowed. The mineral is then broken up so as to allow of it being handled, and is loaded into small cars, which are brought to the workings along miniature railroads that are extended as fast as the coal seam is removed.

Many of the uses of the coal that is so hardly won from its deeply hidden, age-long resting place are obvious to the least observant. We all see its familiar consumption for the warming of houses, for cooking and power-producing, when, transformed into heat, it moves every type of machinery, from the swift and ponderous express engines and the great marine leviathans, down to the myriad machines of our factories and workshops. We know that from it has been produced the gas for our lighting and that it has smelted the metals which provide material for nine-tenths of the mechanical contrivances of mankind. We recognize that coal, in alliance with iron and its compounds, has made modern industrialism possible. But there are other uses to which coal has been put in recent years that are less obvious and equally interesting, if not so essential. The chemical products of coal are one of the marvels of our generation. They are treated elsewhere in this work, in the chapter The Chemist as Creator.

A ton of bituminous coal will produce 10,000 cubic feet of gas, 140 pounds of tar, about 1500 pounds of coke, and 20 to 25 gallons of watery liquid. The use of the gas and the coke is familiar enough; it is the tar and watery liquid that furnish the opportunity for the creative chemist's modern magic.

MODERN METHOD OF LAYING THE DUST

This compressed-air gun is applying a coat of cement to the walls of a coal mine to settle the dust and prevent explosions.

A DEFENDER OF THE CREED OF FAMILY

© Walter Scott Shinn

THEODORE ROOSEVELT, HIS SON, THEODORE 2ND, AND HIS GRANDSON, THEODORE 3RD

"Surely there is nothing so vitally essential to the welfare of the nation, nothing around which the nation should so bend itself to throw every safeguard, as the home life of the average citizen"

ONE MAN AND ONE WOMAN

The Evolution of Marriage and Its Development from Savage Forms into a Sacred Institution

THE UNBREAKABLE BOND OF MARRIAGE

THERE is a curious old doggerel, still current in some sections —

> Change your name and not the letter,
> You marry for worse and not for better,

which expresses the most ancient marriage law now existing. This law can be traced in various forms among all the peoples of the earth, with the exception of a few very low savages, and they probably have only lost it on being broken up and disorganized by conquest.

The old rhyme may seem to embody merely a meaningless superstition, and in our present state of society it has, indeed, become emptied of importance, but in the savage communities of Australia, North and South America, and part of Africa it is connected with a wonderful advance in human thought. The superstition about wedding anybody whose name begins with the same letter is merely a modern substitution for a now-forgotten set of complex rules forbidding marriages between members of the same clan. It is a vestige of a strange and intricate system for preventing marriage between persons closely akin to one another.

It is an axiom in geology that by studying the past we can understand the present, and by studying the present in the light of the past we can discern the forces which are shaping the events of the future. But in many of the problems of society we are able to study the present in the light of the present. We have only to look carefully at the black-fellows of Australia, for example, in order to understand the meaning behind this apparently meaningless superstition about marriage.

Let us take one of the best-known of Australian tribes, the Kamilaroi of New South Wales. This tribe is divided into two clans, which are named Dilbi and Kupathin. These two clans are again subdivided into two castes. The Dilbi is divided into the castes of Muri and Kubi: the Kupathin is divided into the castes of Kumbo and Ipai. The tribe possesses six totems. These totems are sacred animals — the kangaroo, the opossum, the lizard, the emu, the bandicoot, and the black snake. The tribe is further divided into six groups, and each of these groups has its special totem.

Clan	Castes	Totems	Clan	Castes	Totems
Dilbi	Muri Kubi	Kangaroo Opossum Lizard	Kupathin	Kumbo Ipai	Emu Bandicoot Black snake

Every member of the tribe has his or her own clan, caste, and totem — these come down by descent. Now, all these divisions are marriage divisions. Men and women must wed always outside their clan, outside their caste, and outside their totem group. Thus, a man of the Dilbi clan must marry a woman of the Kupathin clan. If he is of the Muri caste, he must take his wife from the Kumbo caste. If his totem is the lizard, he must choose an emu, bandicoot, or black snake wife. Let us suppose he marries an emu woman, then the children are emu children. They enter the Kupathin clan and belong to the Ipai caste. They therefore have to marry into the Kubi caste of the Dilbi clan, and their partners must be taken from kangaroo or opossum men and women.

Dim glimpses of scientific truth among savages who can count only up to ten

Among the Indians of North and South America the system becomes more complicated. Some of the tribes are divided into ten divisions — clans, castes, classes, and sub-classes, with a bewildering variety of totems. Among the black-fellows of Australia there are some tribes with eight divisions; and men of science are amazed at all this curious and intricate organization for preventing intermarriage. Nothing so effectual obtains among civilized peoples.

It looks very much as though they bestow on their children the careful forethought which we only give to breeding champion cattle and racehorses, fancy dogs, and prize fowls. It is said that some of the Australian black-fellows can only count in words up to ten; and even Herbert Spencer was inclined to think that they knew little more than a dog about the way in which children come into the world. Recent research, however, shows that the black-fellow is well aware of what he is doing by his primitive system of eugenics. He long since discovered what Darwin proved by his remarkable study of self-fertilization of plants and the in-and-in breeding of animals.

Savage belief in the council of chiefs that was held after the Creation

The Australians have a tradition that, after the Creation, fathers, mothers, sisters, brothers, and others of the closest kin intermarried promiscuously, until the bad effects of these marriages became manifest. A council of the chiefs was then assembled to consider in what way the evil might be averted, and the result of their deliberations was a petition to the Good Spirit. In answer to the petition, the Good Spirit ordered that the tribe should be divided into branches, distinguished one from the other by different names, after objects animate and inanimate, such as dogs, mice, emus, rain, and so forth, and that the members of any such branch should be forbidden to marry other members of the same branch.

Seeing that the Australian black-fellow understands clearly the full effect of his marvelous marriage system, we may take it that he has much more intelligence than some white men fancy. His legend, however, does not explain how the law of outbreeding came into existence. It would seem as though the totem grouping were the most primitive form of the tribe; for the totem is still the strongest bond among the natives of Australia. Two kangaroo men, for instance, belonging to hostile or foreign tribes, regard themselves as brothers.

The totem group is practically the unit for many social purposes. If an emu man has killed an opossum man, it is the duty of all the opossum men to avenge the death of their totem brother. And, according to the rules of savage justice, all the men of the same totem group as the murderer are guilty of the murder; so the avengers kill the first emu man they meet. In the same way totem brothers help each other in abducting a woman, in attacking an enemy, and in defense. It is not generally a question of blood relationship, for a totem brother may belong to a hostile tribe.

The curious custom which perhaps gave the children "Beauty and the Beast"

There is much evidence, however, in support of the view that the totem group was originally a family group. The American Indians, indeed, still regard the totem as the ancestor of the entire totem group. This quaint idea appears to have inspired many of the strange animal myths so common among barbaric and even civilized races. "Beauty and the Beast" is probably a totem myth; and so also are the tales of Jupiter descending to earth in the form of a bull, a swan, and an eagle.

By means of scraps of folk-lore and legend we are able to trace the existence of totem grouping among practically all the races of the earth. The only peoples among whom it cannot now be discerned are the broken and scattered Veddahs of the forests of Ceylon, and perhaps some disorganized tribes of Fuegians. These seem to have gone back to the family

group; and it is very likely that their present practice of closely intermarrying is a temporary accident, which, if not remedied, will sweep them away with the vanquished Bushmen and the disappearing Hottentot of South Africa, both of whom also took to marrying with kinsfolk.

By tracing the original totem group back to the scattered families which existed before tribal custom originated, we may perhaps carry the law of marrying out of the group into the very earliest stage of culture. It is supposed that mankind at that stage was governed by a rude primal law.

In those far-off days, the group consisted, it is conjectured, of one adult male, a number of females, together with the young of both sexes. As the young males came to maturity, they would be expelled from the group by their sire, as is the case with cattle and other mammals. They would then wander about as the young males of some existing species do, in bands of a dozen or more. At the marrying season of the year, however, the strongest of them would engage in single combat with the lord of some group, and either kill him or drive him, like a rogue elephant, to end his life in lonely ferocity.

The first law of marriage — "Thou shalt not marry within the group"

Then, on this theory, as human feelings developed in the primitive man, and as the children required a longer time to come to their full powers of mind and body, the feelings of maternal love increased in the mothers. They kept their children with them, and this led at last to some of the youngest males being allowed to remain in the family group on attaining maturity. The sire retained his sovereignty over all the females in the group, and so the young male had to win a mate outside the family.

Thus originated the primal law, "Thou shalt not marry within the group." This law was first enforced by the superior strength of the jealous sire, but in the course of time it came to be a traditional rule of conduct, with almost the power of an instinct. Such is the ingenious theory of J. J. Atkinson and Andrew Lang.

Defective though it is in some particulars, it constitutes the only working explanation we have of the origin by natural means of the primal law of marriage. It does not seem likely that the system of forbidding intermarriage was, as the Australian legend pretends, a late invention of the human savage. If there had been intermarrying of near relations from the earliest times, it would be difficult to discover by what means the general strength and health of body had been maintained and developed. No doubt there may have been aberrant forms of marriage in the very earliest ages, but the offspring would be wiped out by the stern process of natural selection.

On the other hand, as Dr. Stanley Hall points out, there seems some ground for thinking that the myth of the fall of man is founded on a dark and terrible event in the history of marriage.

Strange facts from the savage world which throw light on the past

It is probable that very early in our history man was kept in a straight course, in regard to the union of the sexes, by the fact that he was able to breed only in one brief period of the year. The family group was then held together by the care the children required, and the natural affection which they called out in their parents.

Vestiges of a human marrying season in primitive times can still be discerned. It is true that the whale, the elephant, some rats and mice, and several of the lower monkeys are able to obtain so rich and constant a supply of food, that they never really want, and, as a consequence, they have no fixed period of mating. But, as a general rule, animals — especially apes most closely resembling man — begin to mate when fruits are plentiful, and there is no reason for excluding man from the law which prevails in the animal kingdom.

Some rude savages are stated to have, even now, an annual marrying time. Thus it is alleged on good authority that the wild Indians of California, who are among the very lowest of existing savages, have their regular marrying seasons.

The beginning of the spread of population all over the earth

This statement is confirmed by another observer, Mr. Stephen Powers, of the United States Geological Survey, who says of these Indians that "spring is a literal Saint Valentine's Day with them, as with the natural birds and beasts of the forests."

In many parts of the world, tribal marriage feasts are still held in the spring months; and popular customs in England and Germany and other European countries indicate that similar festivals were held there in ancient times. And at the present day there is even in civilized countries a seasonal fluctuation of the birth rate.

Man has thus gone through the same transition as certain domestic animals. In Southern countries the goat and the ass pair throughout the year; the domestic pig — whose supply of food is also assured — now pairs twice a year, while its wild relations have only one mating season; and some cage canaries have now been observed to lay eggs in both autumn and winter. Very likely it was when man became a meat-eater as well as a fruit-eater that he escaped from his restricted marrying season. But the development of this power, which has enabled him to spread over all the earth, must have taken place gradually; and in favorable circumstances it might have at once made for progress in every direction. For with it man's emotional nature expanded, and this in turn added a new stimulus to the growth of his intellectual faculties. He was able to multiply more rapidly, and the number of his offspring urged him to greater exertions and inventions as a hunter.

The natural forces that strengthen the modern marriage system

When, however, man won the extraordinary power of being able to marry throughout the year, he seems to have misused it, and checked his physical and intellectual growth by wild overindulgence. Mankind, happily, succeeded in slowly regaining some of the ground it had lost, by surrounding everything connected with the union of the sexes with fearful taboos and menacing superstitions. Nearly all modern savages regard woman as mysteriously dangerous or "ceremoniously unclean," and their religious marriage rites are performed with the object of lessening the peril of living with a wife. The ancient superstitious fear of woman is one of the chief causes of her social degradation in the lowest stage of culture; but it must be remembered that this degradation was, in its origin at least, a roundabout means of saving the race.

And now, having dealt with the interesting but difficult problem of the origin of the magnificent system of preventing intermarriage which has done so much to benefit mankind, let us endeavor to trace the development of the institution of marriage. Among nearly all the lowest savages, a man usually has only one wife. This seems due mainly to economic causes. In very low stages of society no distinction of class exists, the accumulation of wealth is impossible; and as life is principally supported by hunting, the labor of women is not of very high order.

All over the world there are natural forces that tend to restrict a man to one wife, and a woman to one husband. The sexes are generally about equal in numbers: this makes everywhere for single marriages.

The marriage customs of the peoples of the East

Thus it comes that peoples and nations notorious for their polygamous tendencies are seen to be, on closer study, usually married in single couples. In India, for example, more than 95 per cent of Mohammedans are wedded to one woman. In Persia only two men out of every hundred enjoy the doubtful luxury of a plurality of wives. The mass of the Hindoos are married singly; and among the laboring classes in China, also, it is rare to find more than one wife to one man. It is a mistaken opinion that in what we speak of as a polygamous society most men have more than one wife. The relative numbers of the sexes forbid the arrangement being extended to the whole population; really only the wealthier can indulge in several wives.

As we shall see when we come to deal with the problem of the proportion of the sexes, there are certain factors which at times seriously disturb the equality in the number of young men and women. These disturbances produce grave disorders in society, and sometimes lead to the establishment of abnormal and unhealthy customs of marriage. Polyandry, or the marriage of one woman to several men, is, for example, found in Tibet and India.

The only human feeling with a single absorbing aim

But as we now only wish to trace the main lines of development of the union of the sexes, we must keep in view the forces that make for progress. Chief among these is the passion of love. True love may be said to be a real monogamous instinct. It seems to be the only human feeling with a single absorbing aim. The feeling of fellowship is by its nature diffused; even a mother's affection allows a plurality of objects; revenge does not always desire to have but one victim; and the love of domination needs many subjects. The greatest intensity of love, on the other hand, limits the regard to one person. In the imagination of the lover, the beloved acquires an immeasurable superiority over all other men or women. No doubt in its beginnings the special passion of love may turn upon a small difference of liking, but such differences are quickly magnified by the wonderful effect of emotion upon the imagination. A lover's thoughts and feelings act and react until their object is distinguished in a transcendent way from all other members of the same sex.

The only native American race which has given its women political power

This absorbing passion is not confined to men and women of civilized societies. It is found among savage peoples, and among birds, and some of the lower animals. The love-bird, for instance, rarely survives the death of its mate, even when supplied with a fresh and suitable companion. When love is allowed free play, and is not degraded, the lowest savage is not only remarkable for the purity of his marriage customs but he is nobly distinguished for the high position to which he raises his women. Among the Indians, for instance, the Iroquois never marry more than one wife, and they are the only native race of America who have given to woman any political power. The Iroquois matrons had a representative in the public councils; they had a right to forbid war, and a right to interpose in bringing about a peace. They possessed, also, considerable authority in family matters. Among the Nicaraguans — a people almost wholly monogamous — the husbands are said to have been so much under the control of their wives that they were compelled to do the housework while the women attended to the trading.

The mighty and benign power of love has probably played a larger part in the evolution of human society than the man of science commonly admits. It is comparatively easy to estimate the external forces of progress, and for this reason these forces have been long and widely studied. The result is that their effects have often been greatly exaggerated while the more subtle and profound advance achieved by the various forms of human love has been almost lost sight of.

The taboos which the savage thinks are his protection against women

Unfortunately, scarcely any modern savage feels the highest passion of love. Superstition and custom compel him to regard his women as dangerous vessels of all sorts of mysteriously evil influences. A great deal of his life is spent observing taboos which he thinks protect him from the perils of intercourse with the sex that he regards as weaker and yet more fearful than his own.

In many cases a marriage between savages is a kind of divorce. For instance, all the male Fijians, married and unmarried, sleep at the club-houses, of which there are generally two in each village. In New Caledonia the wife lives and sleeps by herself in a shed near the house, and so do the women in New Guinea. The Nubians have two dwelling houses, one for the

males, the other for the females; and there are American Indian tribes with the same arrangement. The Bedouin tent is divided into two compartments for the men and women; no Hindoo woman must enter the men's apartments; and in Korea there is little intercourse between husband and wife. If a Hindoo wife were to touch the food her husband was about to eat, it would be rendered unfit for his use. The same superstition obtains in Egypt, in various parts of Palestine, in Siam, China, among many Indian tribes, and African negroes. Among the Barea tribe in East Africa the fear exists that if husband and wife sleep together the breath of the wife will steal away the husband's strength. This fear of effeminacy, in its literal sense, is at the bottom of these queer taboos.

Fear of women rather than marriage by purchase cause of wife's degradation

It is not extravagant to say that the almost universal superstitious fear of women in primitive time is the chief cause of the degradation of the wife, and the long lack of progress in all marriage relations.

For this reason we are not inclined to agree with the numerous writers who consider that the degradation of woman began when marriage by purchase was evolved. It is true that woman thereby became a chattel, but the mere fact that she became valuable strengthened the marriage bond. When a wife costs many bullocks, or has to be earned by serving her father for two or three years, the ordinary man cannot afford to get a new wife whenever his fancy changes.

The relations of the husbands to their wives among lower savage races

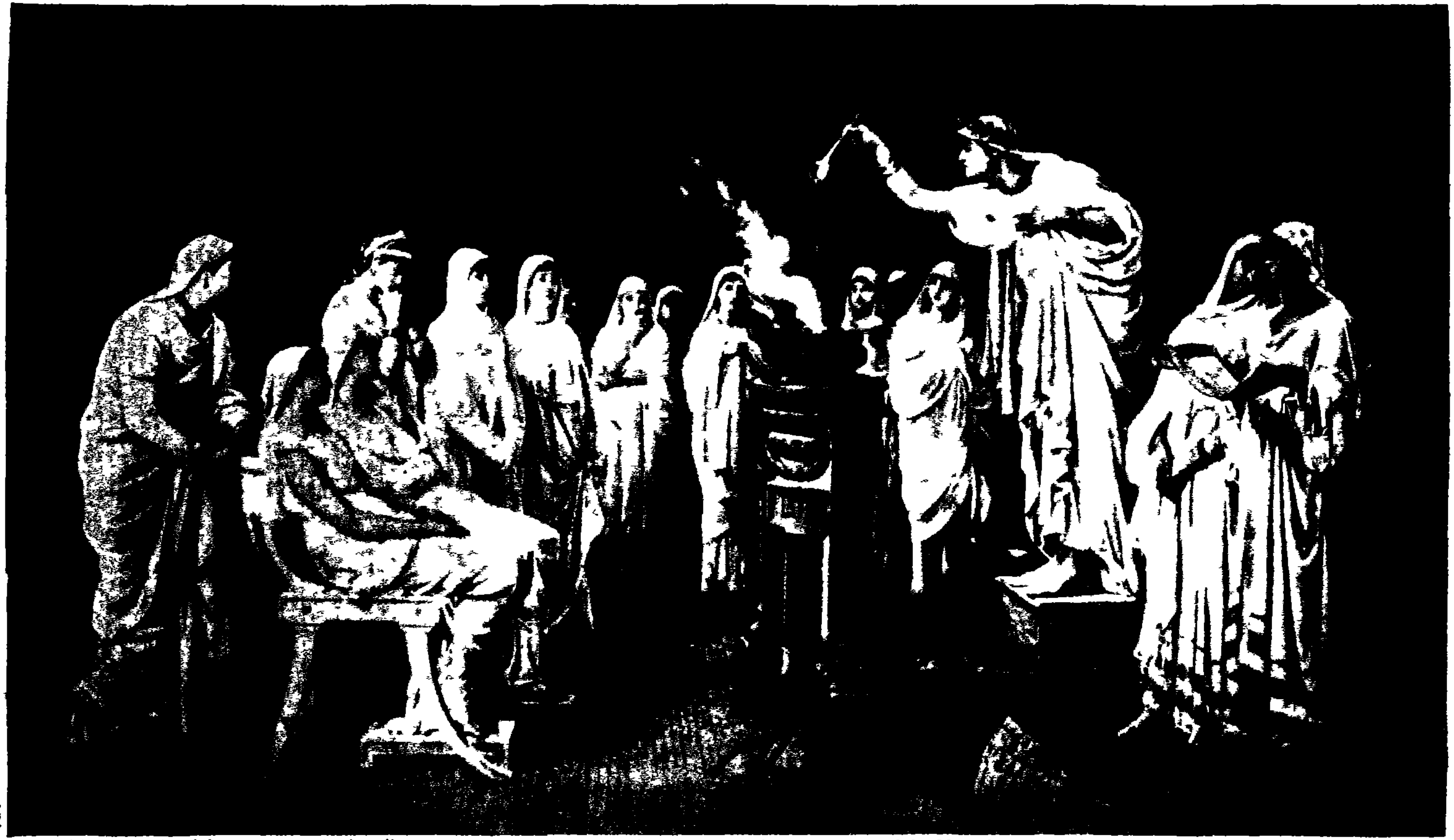
Among nearly all the lower savages who are nominally married to a single wife whom they obtain with little trouble, the duration of the marriage is often very short. The Andaman Islanders, the Veddahs of Ceylon, and certain tribes in New Guinea and the Indian Archipelago are the only people in the lowest stages of culture who are known to be faithful all their lives to a single wife. The Indians of North America, for instance, dissolve their unions as readily as they enter into them; and the Creek tribe has the general custom of one-year marriage. Among the savages in the interior of the Malay Peninsula it is not uncommon to meet persons who have been married forty or fifty times. The natives of Tasmania seem to have been as bad; and so were the Madagascans until they became converted to Christianity.

To put it briefly, among savage races, especially where women are obtained easily and single marriages are common, a man may divorce his wife whenever he likes. As Dr. Edward Westermarck points out, there is often a show of reason for the extraordinary fickleness of the lower savage. The savage woman very quickly loses her good looks; the hardships of a wandering life, the fight against famine, and the bearing of children rapidly make her an old, wrinkled woman. Often when a savage woman has reached her twentieth year the flower of her life is gone. About the same time she may begin to lose her motherly qualities. Bushman women become sterile a few years after reaching maturity. Among the Fulah of the Sudan, it is rare for a woman older than twenty to become a mother; and in Unyoro, one of the provinces of British East Africa, Emin Pasha never saw a woman over twenty-five with a baby in all his travels.

Savage marriages and the effects of war on the marriage system

These facts have a bearing, not only on the short duration of savage marriages, but on the problem of the almost general inclination to polygamy among the lower races. Many writers attribute rather too much to warfare in shaping the forms of marriage. It may be that the continual wars between the North American Indians kept down the numbers of men, and left many women the alternative of remaining unmarried or becoming the second wife of some warrior. But in Australia where there are more male savages than female, the old men of the tribe keep so many young wives each that the young men have sometimes to wait until their thirtieth year before they are able to get married.

THE WOMEN INVESTED WITH DECISIVE POWER IN THE DAYS OF ANCIENT ROME



A notable example of the mystery which still environs women in Oriental countries is the institution of the Vestal Virgins, the maidens of ancient Rome who guarded the temple of Vesta, the goddess of home life. They lived in a house in the Sacred Way of the Forum, and during the thirty years in which they were vowed to chastity they were invested with extraordinary powers, having sometimes a decisive voice in life and death. The Virgins are here shown at one of their ceremonies.

It is not in war and in other external conditions that the original source of man's sins against love lies. Pride of life and other baser feelings led him astray. He had the true light within him. The primitive Veddahs of Ceylon prove that; for they, at least, kept the flame of love pure and bright in their hearts, while they crouched in naked misery in their forests. Where all over the earth man rose to power and wealth, he degraded himself into a polygamous animal when he had the opportunity. Even the ancient Teutons, whose virtues Tacitus greatly commended to the decadent Romans, took several wives when rank and wealth enabled them; and so did the Scandinavians.

Yet, to the peoples of northern Europe and their offshoots, the Dorian Greeks, the Romans, and the later nations that swept southward from forest and fiord, we must allow the high honor of evolving the modern lasting marriage of love between a single man and a single wife.

The improved condition of wives who are married by purchase

They began, like many other races, with marriage by purchase. This form still obtains among many savage peoples, and it is seen in its full efficacy among tribes and nations in the agricultural stage of culture. The women do most of the work of farming, and they are, therefore, as valuable to their fathers as they are to their husbands. The practice of serving for wives obtains among rude savages, such as the Bushmen and the Fuegians, who possess little or no property, and yet, the men of both these very low races are distinguished by their love for their wives, and their family ties are very strong. These facts surely go to show that when women in savage or barbaric societies have to be purchased by labor or goods, their position is generally improved. They become too expensive and also too useful to be changed for a whim. Young Zulus who are without cattle have to wait many years before marrying. So in the New Britain group of islands, the price of a bride is often so high that the intending husband is middle-aged by the time he can afford a wife.

The marriage by capture romance built up on a slender foundation

This state of things leads naturally to the very curious variation of marriage on credit. When marriages of this sort take place the wife and her children cannot, as a rule, leave the parental home until all the installments are paid. In Unyoro, to quote Emin Pasha again, if a poor man is unable to pay the cattle for his bride, he may hand them over slowly, one by one; the children born in the meantime belong to the wife's father, and each child must be redeemed by a cow.

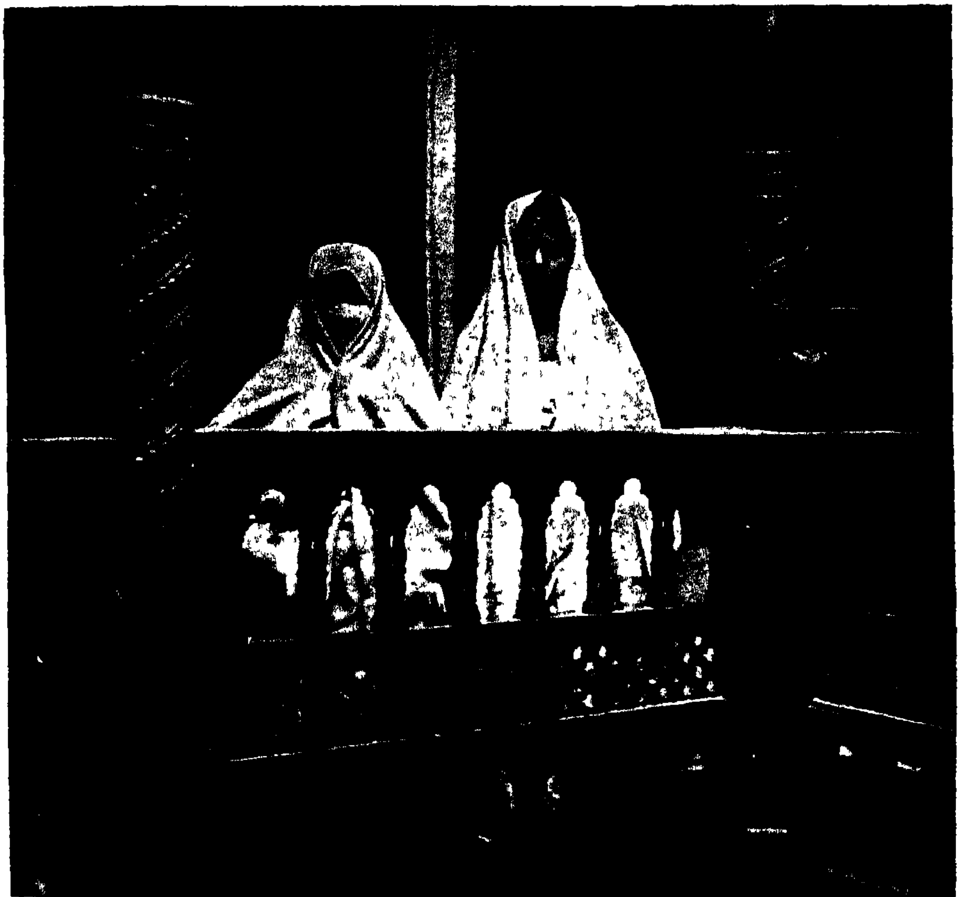
It has often been suggested that marriage by purchase grew out of marriage by capture. This view has an engaging simplicity and reasonableness, but savage customs are very complex, especially in regard to the union of the sexes; and, besides, it has never been proved that marriage by capture was ever a general practice. Few theories of primitive society have had such a vogue as that of marriage by capture, and few have been built on such slender foundations. The tinge of romance about it has, no doubt, had something to do with its popularity. But, as Ernest Crawley has now clearly shown, the widespread wedding ceremonies which have been mistaken for vestiges of a system of forcible abduction are only designed to bring out the ordinary, delightful fact that the bride is shy, and that her mother is loth to part with such a treasure of a daughter.

Of course, there have always been very many elopements, and women have been carried away, over the bodies of their fathers and brothers, but these were accidents, and they did not affect the evolution of the institution of marriage.

Marriage by purchase is in its origin very obscure. The obscurity arises from the fact that the bride-price seems to have been customary long before the idea of buying and selling became connected with marrying and giving in marriage. So we get back to the dim region of primitive superstition. Now, gifts among savages are connected with savage ideas about magic. By giving anything belonging to

you, you put yourself in the power of the person to whom you give it; for if he is evil-intentioned he may be able to cast a dreadful spell upon you by charming something that belonged to you. A gift, therefore, becomes the sincerest evidence of friendship.

The principle involved is personal and religious; it is a pledge rather than a lose all her rights in her bride-gifts. Marriage among the Kaffirs, for instance, is not a matter of mere barter. The cattle paid for the bride are divided among the male relations, but they hold them partly in trust for the wife and her children. For, if she is left a widow, she can demand assistance from everybody who has had a share in her dowry. Moreover, the father provides a



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THE MYSTERY SURROUNDING WOMEN AMONG ORIENTAL RACES—TWO WOMEN OF ALGIERS

price. Bride-gifts thus had originally a religious importance. But as the commercial instincts of the parents ripen, and daughters are found to have their price, the old idea fades into the light of common day, and marriage becomes partly a business transaction. But even among peoples where marriage by purchase obtains in its grossest form, the bride does not always marriage ox, which is a purely religious gift. It is known as "the ox of the bride," and it is eaten at the marriage feast. This ox stands for the value of the girl; it is also a pledge to the bride and bridegroom that when the father dies his spirit will not haunt their home; and it is, besides, a superstitious token that the marriage will be blessed by many children.

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RUTH

Whose marriage to Boaz is one of the Bible evidences of an interesting Jewish marriage custom by which property descended to women

Marriage by purchase has an especial interest for us. Old English laws speak bluntly of "buying a maid"; and in Germany, throughout the Middle Ages, "buying a wife" was the common phrase for marriage. It flourished in the England of King Alfred; and Canute found it necessary to make a law forbidding the guardians of a girl from selling her in marriage against her will. But perhaps this was a recrudescence of barbarism due to the Danish invasion. For in spite of the commercial appearance of the Teutonic marriage, the position of a married woman was a fairly happy one. For many years the old, harsh forms endured, but the spirit of the ceremonies seems to have changed for the better long before the spread of Christianity. At first a part of the purchase money was given to the bride, and then the whole of it was bestowed upon her as a dowry.

No doubt the forces behind the happy evolution of marriage by dower out of marriage by purchase were of a moral and spiritual kind. Marriage by purchase had fulfilled its object in making the union of the sexes stable and lasting, and out of the stability and permanence grew a stronger and purer feeling of love between the man and the woman, which helped to give the woman more importance in the national life. Marriage by dower developed in turn, owing to the fact that it put still greater difficulties in the way of a husband who wanted a divorce. Among the Teutons of early times, the bride-price which was handed over to the woman as her marriage portion became her exclusive property, of which her husband could not dispose. And in addition to this wealth, which generally consisted of cattle, she received from her parents an endowment — like the modern French *dot* — which was a sort of compensation for her inheritance, or an advance on it. This was also her private property, in that her husband had to return it to her if the marriage was ever dissolved. Thus an ordinary man who put away his wife lost a great

ONE MAN AND ONE WOMAN

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BY LORD
LEIGHTON

deal of his property; and he had, besides, as in the old days of marriage by purchase, to provide another bride-price if he wanted to marry another woman.

For some hundreds of years after the time of Christ marriage remained a civil contract, in which no priest took part. It was a private family matter, like the selling of a house. In England it consisted of two separate treaties — the wedding or the betrothal, in which a ring or a penny was presented to the bride as earnest-money; and the real marriage, or giving of the woman, when the cattle were handed over, and the girl was made a wife. The modern engagement-ring now represents the old earnest-money given to the intended bride; and the best-man of the bridegroom is the sole representative of the friends who used to stand surety at the betrothal for the payment of the bride-price.

The modern civil marriage is generally regarded as an extraordinary innovation. But it is not so in fact. It was not until the tenth century, in England, at least, that a marriage became an ecclesiastical institution, and a priest took any part in the marriage service. Even then the marriage rites were only performed before the door of a church, where the priest closed the ceremony with a blessing. Throughout the Middle Ages the principal act of the marriage celebration — the consent of the parties — was conducted at the porch of the church in England, France, and Germany. And in England marriages continued to be celebrated at the church door until the sixteenth century, when the liturgies of Edward VI and Elizabeth first required the ceremony to be performed within the sacred building.

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A TOTEM POLE

The totem is an animal held sacred by certain primitive races, and totem poles are set up in very many villages, especially those of Alaskan Indians.

As Dr. Westermarck, perhaps the best authority on the subject, says: "The history of human marriage is the history of a relation in which women have been gradually triumphing over the passions, the prejudices, and the selfish interests of men." The tale of the evolution of marriage is really the story of the growth in strength, purity, and constancy of the divine spirit of love. Some persons at the present day seem inclined to doubt whether we have reached the highest stage in the development of the institutions which regulate the union of the sexes. Man's natural instinct still breaks through civilization. Our hearts need to be cleansed, and our wandering imaginations purified, before we have completely reduced to practice the high idea of monogamy. We have still much to learn from the most primitive people in the world, every man of whom remains faithful until death to a single wife.

On the other hand, the notion of evolution and progress can be pushed too far. There is no progress in marriage beyond monogamy. Everything put forward as a pretended substitute by writers of the revolutionary school is a degradation from a standard of perfection which we have yet fully to attain. Savage and barbarous races in various parts of the world are carrying out all the so-called "advanced ideas" on marriage found in our recent literature of rebellion, and in every case it is clear that these ideas are a degradation. Marriage for life between one man and one woman is a sacred institution; it is built out of the tears and blood of many martyrs, out of the sufferings of the countless women who existed in the long ages before it was established.

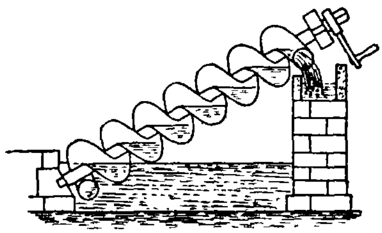
INVENTORS

ARCHIMEDES

A Great Scientist before the Time of Christ

ARCHIMEDES was born 287 B.C. at Syracuse, Sicily, then one of the chief cities of the Grecian world. The son of a geometer, and on terms of intimacy with Hiero, king of Syracuse, and with Gelo his son, he was educated in part at the great school of Alexandria, and maintained a regular correspondence with the students of geometry of that city. Regarded as the most perfect type of scientific intellect that has ever appeared in the world, he appeals to the popular mind by his inventions, and to the scholar by his researches and discoveries in pure science. It was to science that he was wedded. He scorned the mighty mechanical inventions of which he was the creator, and at which all the world wondered. He invented to order. Had he been living today, we should have asked him for the long-sought storage battery for electricity, or for a perfectly stable airplane, and we probably should not have asked in vain. King Hiero ridiculed his recondite studies, and asked for something tangible. As Plutarch tells us, Archimedes regarded his inventions only as among the amusements of geometry. "Nor had he gone so far, but at the pressing instances of King Hiero, who entreated him to turn his art from abstracted notions to matters of sense, and to make his reasonings more intelligible to the generality of men, applying them to the uses of common life."

Archimedes responded to his sovereign's call. He invented pulleys and windlasses, the water-screw or screw-pump, that endless screw which we find in operation today in ten cent toys and five thousand dollar automobiles; he invented various hydraulic and compressed-air machines;



ARCHIMEDES' WATER-SCREW

and the burning mirror, as to which the story is not disproved that he destroyed part of the Roman fleet when it appeared before the walls of Syracuse. For the defense of the city against the army of Marcellus he created engines of war whose fame has ever since rung through the world, towering structures which suddenly rose above the battlements, to hurl stones or masses of lead against the assailants, which dropped beams endwise on their ships, or flung out hooks which, grappling the galleys, tilted them into the air, then let them fall slanting to the bottom of the sea.

Equally startling defensive measures met the attack on the land side, and the terrified Romans could but sit down and wait. They starved the city into surrender, but the operation took three years. Archimedes, having done his duty, and

created the things for which he had been asked, had gone quietly back to his studies; and, when the Roman soldiery broke in they found him pondering a diagram in the sand. It was by mistake that they slew him, for they had been expressly commanded to spare the distinguished man by Marcellus. The latter buried

ARCHIMEDES WORKING OUT A PROBLEM AS THE ROMAN SOLDIERS COME TO KILL HIM

him in a noble tomb, which was discovered and restored more than a century later by Cicero. It bore a representation of a cylinder circumscribing a sphere, with a verse indicating that Archimedes regarded as his greatest achievement the measurement and mutual proportions of these two bodies.

The contributions of Archimedes to pure science have long been absorbed into the learning of the present-day world. His results were attained by infinite patience, and also by brilliant intuition. Of the latter, the well-known story of his detecting the alloy in the king's crown is typical. Hiero had given a known weight of gold to an artificer with which to make him a crown, and, suspecting a cheat, asked Archimedes to tell him whether base metal had been substituted for any of the gold. Archimedes was puzzled until one day, stepping into a bath, he caused the water to run over. He had mastered the secret.

and ran through the streets to his home in a state of nudity, crying, "I have found it!" It had flashed upon his mind that a body in water displaces a quantity of water of equal volume. If, therefore, the crown and an equal weight of gold were placed separately in a vessel of water and the overflow occasioned by each noted, the presence or absence of an alloy would be manifested. Starting from this point he composed his masterly treatise upon floating bodies, the first attempt made to estimate the pressure exercised by the elements of a fluid.

Archimedes died in 212 B.C. His works live after him. He was right, and his master was wrong; it is the results of his abstract studies that have mattered to the world. Some of his inventions have been in general use to this day, but his teachings are of the foundation of all learning.

SIR RICHARD ARKWRIGHT

A Founder of the Modern Cotton Industry

RICHARD ARKWRIGHT, the English inventor, was born at Preston, Lancashire, on December 23, 1732, the youngest of thirteen children, whose parents were extremely poor. He received but scanty education; and, indeed, it was not until he had turned fifty that he was able really to master spelling and grammar. He began his career early in a barber's shop, and, setting up for himself in a cellar at Bolton, displayed the sign, "Come to the subterraneous barber. He shaves for a penny." When his rivals brought down their prices to his level, Arkwright reduced his to a halfpenny. He married first in 1755, but seems soon to have been left a widower, for he married again in 1761, and, abandoning his barber's shop, set out as a traveling wig-maker. He bought human hair on his travels, and, utilizing a secret chemical preparation, dyed his wigs the color desired by his patrons.

By what steps he was led to the invention of his spinning-frame is not known, but cotton was king in Lancashire then as it is today, and to every cottage that he went its manipulation represented the bread of life. Up to 1767, when Hargreaves invented his spinning-jenny, the workers had been able to manage but one spindle at a time. The weavers had had to furnish themselves as well as they could with warp and weft for their webs, and, when the cloth was made, sell it wherever they could discover a market. At this time certain Manchester merchants began to organize the labor of the cottagers. They sent their agents far and wide, and supplied the weavers with foreign or Irish linen yarn for warp (that is, the stiffening cross-thread), and with raw cotton which before it could be used had first to be carded and spun by means of the old

SIR RICHARD ARKWRIGHT

spindle or distaff, and then used as weft (the longitudinal threads) This stimulated the industry, but the demand for yarn far exceeded the supply.

Matters assumed a more promising aspect with the invention by Hargreaves of his spinning-jenny, which multiplied the number of spindles that the operative might use, from one to eight and afterwards more. But the resultant yarn was too soft for use alone; it had still to be combined with the linen warps; and it is interesting to recall, as a side-light upon old trading methods, that the Irish manufacturers complained of the sale to England

of Irish warps, as creating a scarcity in Ireland, and so forcing up prices. It was in 1767 that Hargreaves completed his jenny, though he did not patent it until three years later, and it is probably only a coincidence that in the former year Arkwright began his own investigations. There is no evidence that he knew anything of Hargreaves's inventions; trade secrets were hoarded like a miser's treasure. But his vigorous intelligence had already grasped the theory of his spinning-frame, by which to abolish the old labor of work by hand, and at the same time to produce a thread stout enough to serve both as warp and weft.

It was in 1767 that Arkwright sought out John Kay, a clock-maker of Warrington, and asked him to make him the first model of his spinning-frame. The attempt was made, in later years, to prove that Kay betrayed the secret of another man to Arkwright, and that the latter's invention was in reality that of the man said thus to have been wronged. But there is every reason to believe that Arkwright's own account of the matter is correct — that he got his idea from seeing red-hot iron being drawn out through two pairs of rollers, the second pair moving more quickly than the first. Here, he thought, was a manner in which cotton, after being cleaned and carded, might be treated. Arkwright threw himself wholly into his new scheme, gave up the wig business, and brought himself so low pecuniarily that when he applied to a certain instrument-maker for assistance the man of substance turned in contempt from the unkempt genius before him. He did consent, however, to grant Kay the loan of a smith and tool-maker for the heavier part of the apparatus; while Kay under the instructions of his poverty-stricken master, undertook the clockwork part of the business. Arkwright gave 1768 as about the year of his invention, but stated that it was effected only after "many years' intense and painful application."

When the first model was finished, the inventor, accompanied by Kay, set off to Preston, where they exhibited it in great secrecy to a possible patron in the old grammar schoolhouse. A striking picture has come down to us of the preliminary trials with the machine which was to endow Lancashire in particular, and the British nation generally, with such wealth. The care that they took to screen their operations created suspicion. Two aged women, living near the schoolhouse, seem to have crept fearfully on tiptoe into the gooseberry plantation in front of it, and to have told with fine imagination of the hideous witchcraft that was being practised within, of the weird humming which suggested that the devil was tuning his bagpipes, and of Arkwright and his confederates dancing a hornpipe. In reality there was not much enchantment in the matter. The prosecution of his plans brought the inventor to such straits that, when he was asked to go to the polls to record his vote, he declined until those who sought his suffrage gave him a good suit of clothes in place of the rags to which he was reduced.

Lancashire was cotton mad; it was machinery mad in quite another sense; so, warned by the experience of others, Arkwright set up his first commercial machine in Nottingham, where, assisted by various enterprising people, he opened his first works, and drove his machinery by horse-power. This proving too costly a method, he established himself at Cromford, in Derbyshire. Here he had excellent water-power, and began operations with success.

But the Lancashire manufacturers, who had been crying out for the very article that he had to offer, now refused to use it. They were prepared to injure themselves in order to ruin him. He was driven to stocking-making, and then to the manufacture of calico. His success was brief, for the men of Lancashire invoked an Act of Parliament of 1736, designed to protect the woolen industry, by imposing a tax of threepence per yard on such fabrics when exported, and prohibiting its use at home unless it embodied a linen warp. But the indomitable Arkwright made representations to the government which brought about the repeal of this absurdity, and in 1774 manufacturers were free to fabricate "stuffs wholly made of the raw cotton wool."

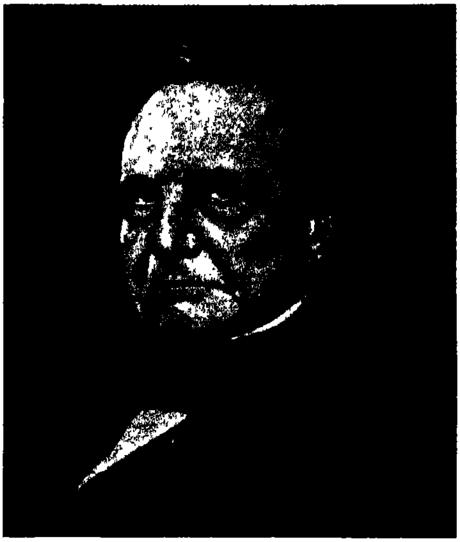
In the following year, Arkwright patented a great development of his machine. The new method embraced the entire process of cotton manufacture, carding, drawing, roving and spinning — a marvelous machine for such an age, and from the brain of a man entirely self-taught in mechanics. The invention gave an enormous impetus to the cotton trade of England. Supplies were vastly increased, prices for yarn and for the finished article were reduced, the output was multiplied a thousandfold. Forthwith Arkwright brought into being the modern factory system. He organized with care and with humanity and, considering the character of his materials, achieved marvels.

But his real battles began only when success seemed assured. He built his own factories, he licensed other manufacturers to use his patents. Yet though individual and collective prosperity was increased by his invention, the masses hated his machines. They wrecked his mill near Chorley, while the police and military, encouraged by his trade rivals, looked on with folded hands. Added to this, he had to combat the knavish practices of manufacturers who, while doing all they could openly to injure him, secretly stole his patents and set to work with his machines. His first action against Colonel Mordaunt, backed by a strong combination of Lancashire manufacturers, was lost solely on the ground that the description in his specifications was not sufficiently clear. The whole question was finally brought before the Court of King's Bench, when his claim to the inventions patented was for the first time called in question. The jury decided against him; his patents were canceled, without, so far as we can judge today, a shred of credible evidence against their *bona fides*.

However, he still held an incomparable position in the manufacturing world, amassed a great fortune, and had the joy of attaining some degree of scholarship, and of seeing the country's trade increasing by leaps and bounds as the results of his labors. He died at his Cromford works on August 3, 1792, six years after he had been knighted by George III.

CHARLES BABBAGE
The Man Who Made the First Counting Machine

CHARLES BABBAGE, English inventor and the maker of the calculating machine, was born near Teignmouth, Devonshire, on December 26, 1792. Being a delicate child, he was at first privately educated, but took naturally to mathematics, possibly inheriting this taste from his father, who was a banker. When he entered Trinity College, Cambridge, he found himself a better mathematician than his tutors, but profitably pursued his studies in company with Herschel and Peacock, with whose assistance he founded, in 1812, the Analytical

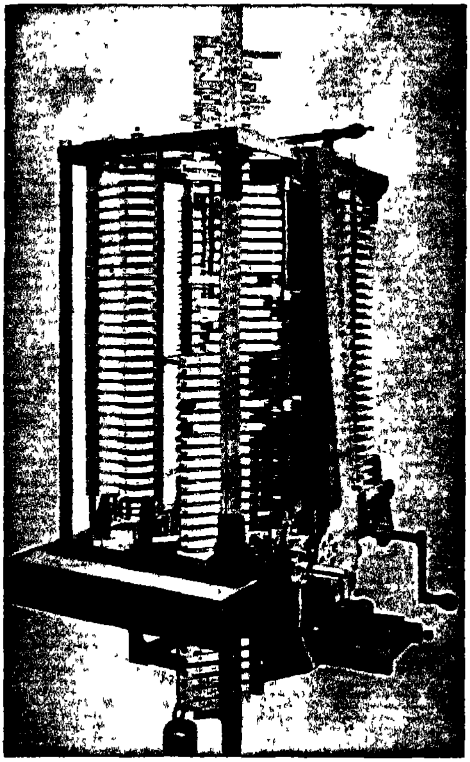


CHARLES BABBAGE

Society. The three friends published, four years later, a translation of Lacroix's "Elementary Treatise on the Differential and Integral Calculus," and two volumes of "Examples" with their solutions, volumes which, it is declared, gave the first impulse to a mathematical revival in England.

Quitting Cambridge in 1814, Babbage established himself in London, became a fellow of the Royal Society two years later, but in after life poured scorn upon the methods of this body, and by his criticisms helped materially to found the British Association. He also took an active part in founding the Astronomical

Society. While associated with Herschel in repeating Arago's experiments on the magnetization of rotating plates, he invented the astatic needle, this being a needle without polarity, having its directive property destroyed by the proximity of another needle of the same intensity fixed parallel to it, but with the poles reversed. But it is upon his work in connection with the calculating machine that his fame depends.



BABBAGE'S ANALYTICAL ENGINE

Primitive calculating machines for the performance of single arithmetical operations had been in existence since the seventeenth century, when the first was invented, in 1642, by Pascal. Babbage fashioned a machine which calculated an entire table, the principle being worked out as the result of refined mathematical processes which gave him for basis the "method of differences." The numbers composing nearly all arithmetical series can be formed by the repeated addition to fundamental numbers of a common difference or element, for which work, as he demonstrated, machinery was eminently fitted. By means of his machine he hoped to eliminate many of the serious errors which had crept into astronomical, navigation, and other tables. The invention was favorably reported upon by eminent scientists, and the British government of the day agreed to subsidize the inventor. Elaborate workshops adjoining Babbage's house were eventually set up at public cost, and in these were fireproof rooms designed to receive his precious drawings and the valuable tools he had invented for the work.

The machine was never really completed, for, before it reached its final stage, the fertile mind of the inventor saw infinitely greater possibilities for a machine of greater scope, which was to be not a "difference" but an analytical engine. Eight years passed before he could get the government to declare whether or not they would continue to aid him At last they decided against further expense. In addition to £6000 that he had spent, the government had laid out £17,000 and the goal had not been reached. So the great scheme fell to the ground, and only models and drawings remain of a machine which was to revolutionize mathematical science

Since the day of Babbage many and wonderful calculating machines have been invented, but he was the great pioneer. His writings, his own work, his betterment of tools, paved the way for others with energy sufficient to push home their theories, a faculty which Babbage, with his indifferent health and nervous excitability, seemed to lack.

Babbage paid great attention to the factory and workshop practices of England and of the Continent, and his "Economy of Machinery and Manufactures" was described by a critic as "the hymn of machinery." If he failed to reach finality with his own inventions, Babbage vastly stimulated others, and was a considerably greater force in the nineteenth century than is now commonly recognized. He died at his house in London on October 18, 1871, within sight of his beloved workshops.

ROGER BACON
The Wonder-Man of the Middle Ages

ROGER BACON, the father of modern scientific learning, was born of a good English family, upon an unknown date in 1214, at Ilchester, Somerset. Perhaps the most fascinating figure of his era, the monk philosopher was far in advance of his time. His knowledge of the law of optics enabled him to invent the magnifying-glass; and he described a telescope, though whether he wrote of a possibility or as of something that he possessed there is nothing to show. That he invented, or at least knew how to create, gunpowder, seems to be beyond question. He investigated and explained the nature of the rainbow, and the reason of the increased size of sun and moon on the horizon, and his writings led later to the invention of spectacles. His rectification of the errors that prevailed in the calendar was another proof of the versatility of his genius.

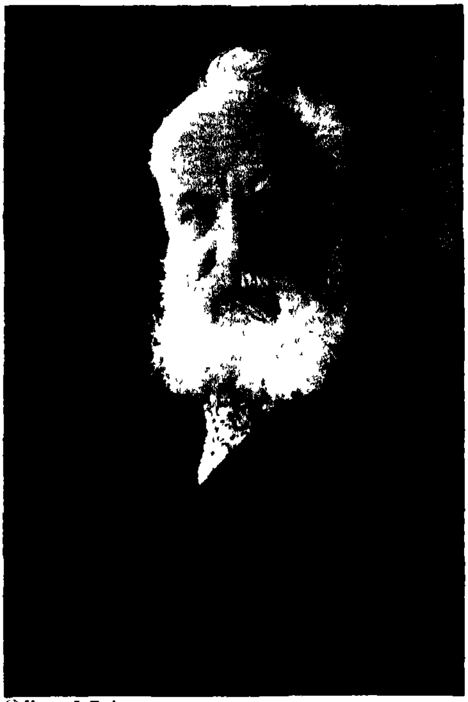
These achievements of Bacon were very remarkable, considering the age in which he lived, and they were still more remarkable when we remember the extraordinary circumstances in which they were effected. Although his family had been impoverished in the troublous times of Henry III, there remained sufficient of the estate to send him to the university at Oxford, and afterwards to Paris, which was then the center of the intellectual life of Europe. Here he took his degree of doctor of divinity. Returning to Oxford he joined the order of the Franciscans about 1240, and threw himself enthusiastically into the studies and experiments, principally in alchemy and optics, which led to such remarkable discoveries in various branches of science that, especially in connection with his imprudent expressions, caused his orthodoxy to be doubted and even led to his being accused of dealing in the black art of magic. He believed in and sought the elixir of life and the philosopher's stone, and though he insisted that mathematics must be the foundation of astronomy, his faith in astrology led him to declare that by thus mastering the secrets of the stars we should cause them to exhibit to us the influences regulating temperament and the predisposition of character. This brought him into conflict with the teachings of the Church, and his immediate superiors thereupon forbade him from publishing any books out of the order "unless they were examined thoroughly by the Minister General or by the Provincial together with his definitors in the provincial chapter . . . under pain of losing the book and of fasting several days with only bread and water." He was given other duties in France and the prohibition lasted some ten years.

But when Guy de Foulques, who when he was papal legate in England had desired but, owing to the prohibition, been unable to see Bacon's writings, became Pope Clement IV, he commanded him to send him his works secretly, ignoring his superiors. Bacon accordingly prepared his "Opus Majus" and sent it by his favorite pupil in 1267. It was an encyclopedia in which he reviewed the whole field of knowledge, physical, moral, intellectual and theological, and embodied all his ideas and proposals for the study of nature and the languages. He also sent the Pope a burning mirror and a number of drawings illustrating problems in physics. His "Opus Minus," finished the same year, recapitulated the points made in the larger work and his "Opus Tertium" amplified them both in some of their details. What use the Pope made of these books must have been slight for he died in 1268, soon after receiving them. But for ten years thereafter Bacon was freed from the restraint of the former prohibition.

But in 1278 the head of the order of the Franciscans, Jerome of Ascoli, afterward Pope Nicholas IV, forbade the reading of his books, and "condemned and rejected his doctrine which contains many suspect innovations by reason of which he was imprisoned." He returned to Oxford in 1288 and died there, probably in 1294.

The cloud of suspicion under which he lay made his writings for long comparatively a closed book, but little by little his teachings came to light. While he could not entirely rid himself of the errors of his time, in many respects he was cen-

turies ahead of it. Modern scientific inquiry begins with him; and though he could not penetrate the mists which hid the absurdities of alchemy and astrology, to his labors in these fields may well be applied the saying of Francis Bacon: "The pursuit of alchymy is at an end. Yet surely to alchymy this light is due — that it may be compared to the husbandman whereof Æsop makes the fable, that when he died, told his sons that he had left unto them a great mass of gold buried under-



© Harris & Ewing
ALEXANDER GRAHAM BELL

ground in his vineyard, but did not remember the particular spot where it was hidden; who when they had with spades turned up all the vineyard, gold indeed they found none; but by reason of their stirring and digging the mould about the roots of their vines, they had a great vintage the year following: so the painful search and stir of alchymysts for gold hath brought to light a great number of good and fruitful experiments as well for the disclosing of nature as the use of man's life."

ALEXANDER GRAHAM BELL

Who Carried Speech across the Earth

ALEXANDER GRAHAM BELL, an American scientist and the inventor of the telephone, was born in Edinburgh on March 3, 1847, and educated there and at London University. Deeply interested in his father's system of instruction for the deaf and dumb, he followed him to Canada in 1870, made himself master of his subject, and coming to the United States, became professor of vocal physiology at Boston University. Six years later he exhibited an electrical invention by the aid of which he sought to make speech visible. That instrument was the beginning of the telephone. It was designed not indeed to enable the deaf to hear, but to see speech. The actual words themselves did not, of course, become visible. Speech caused a delicate metal reed to vibrate and to transmit an electric current to the opposite end of a wire, where the vibrations of the first reed were reproduced by a corresponding reed placed near a second magnet. The process is described elsewhere in this work.

While he was experimenting in this direction he discovered that he had approached the solution of a problem far mightier than he had contemplated. Instead of serving the deaf only, he had within his grasp the potentialities of a scheme which could serve all mankind. For the machine, by modification and refinement, was made to transmit not merely the vibrations of the reed: it carried sound, resolved it into waves, transmitted them in that form, rebuilt them at the other end of the wire into sound — the tones of the voice which had uttered the sound.

Thus the telephone, which is now an indispensable adjunct to the daily life of the entire civilized world, is not yet fifty years old, and results from the benevolent attempt of an inspired brain to put the few deaf in communication with the rest of humanity. The long line of experience, ending in one half of a continent being put into instant communication with the other half, began with tests made by the first instrument upon a dead man's ear!

Bell received a patent for his apparatus in 1876 and although other inventors claimed priority of invention his rights were confirmed by the Supreme Court, and the credit for putting the invention into practical shape is now conceded to him. A company was formed to improve and exploit the apparatus, and from the monopoly the patent created Professor Bell received large royalties and dividends. He founded and endowed the American Association to Promote Teaching of Speech to the Deaf and the Volta Bureau for the increase of knowledge relating to the deaf. Professor Bell was also the inventor of the photophone, of an induction balance and telephone probe for painless detection of bullets in the human body (for which he was awarded the degree of honorary M.D. by Heidelberg University at its 500th anniversary) and, with others, of the graphophone. He was an officer of the Legion of Honor and received the Volta prize from the French government and numerous medals from scientific bodies all over the world. He died at Baddeck, Nova Scotia, on August 2, 1922.

EMILE BERLINER

The Inventor of the Gramophone

EMILE BERLINER, an American inventor, the originator of the gramophone and improver of the telephone, was born in Hanover, Germany, on May 20, 1851. He was graduated at Wolfenbüttel in 1865 and came to the United States in 1870. Not content with his daily round of toil as a salesman in Washington, he gave up his nights to the study of science, being especially interested in electricity. In order to unite practical experience and theoretic investigations, he learned telegraphy. One evening he was trying the key in a fire-alarm station, when the skilled operator told him to strike harder, explaining that by using more pressure the current was made intenser, and the sending distance was increased.

The operator was unable to account for this curious fact; he only knew that it *was* so. But young Berliner was interested in the theory of the matter. He had sat up at night studying the problem that baffled the inventors of the telephone — the problem of getting a clear reproduction of the voice. He now saw in a flash that differences in pressure could be made use of in a new kind of transmitter. Instead of the iron membrane and magnet employed by Alexander Graham Bell, that transmitted very feeble sounds, he constructed a microphone transmitter which reproduced much louder effects. In 1877 his invention — that made practical telephony possible — was finished, and was acquired by the newly organized Bell Telephone Company, and in 1878 the young inventor was appointed chief inspector of instruments. He further improved the telephone by using an induction coil in the transmitter and he has patented numerous other telephone improvements. Then his interest in the electrical side of voice-reproduction was somewhat diminished by a growing attraction to the mechanical aspect of the problem.

He wanted to do for the talking-machine what he had done for the telephone. In the case of the early talking-machines, he came to the conclusion that the method of recording sound-waves by the varying depths in a groove of wax was defective. Sounds were represented by innumerable hills and valleys at the bottom of tiny ravines in the waxen disc. The greater the depth of one of the valleys, the greater the resistance that the wax offered to the stylus. So the record could not be exact. And when the sounds were reproduced by sending another stylus jolting down the ravines, and communicating its vibrations to a membrane, there was often a tendency for the stylus to jump from one hill to another, and neglect the valleys.

Remarkably simple was the means by which he overcame these defects. He kept the stylus steady by making it run along a level groove in the wax. It was in the sides of the groove, and not on the bottom, that the sound-waves cut out minute caves and headlands. The sideways action or motion of the stylus is the original principle of the gramophone, invented by him in 1887. By keeping the groove at a constant depth, the use of an expensive

mechanical screw to guide the stylus is avoided, for the level groove acts as an admirable guide. Thus the mechanism of the new talking-machine is simplified, and at the same time a higher accuracy of reproduction is obtained.

Dr. Berliner was the first to make and use the light-weight, air-cooled, internal combustion motor, used with revolving cylinders in flying-machines. He was always deeply interested in matters of national health. For many years he has conducted a national campaign against unclean methods of handling the milk supply, and the milk conference that met in Washington in 1907 was planned by him. He feels certain that progress in science and sanitation will at last free the younger generations from the wide-spread hazard of early death, and, by his philanthropic and educational labors, he is doing an important share in the noble task of saving mankind from preventable disease and disaster.

SIR HENRY BESSEMER
The Inventor Who Began a New Era in Steel

SIR HENRY BESSEMER, the inventor of the process of steel-making that bears his name, was born at Charlton, near Hitchin, Hertfordshire, England, on January 19, 1813, of Huguenot descent. The son of a genius whose talent profitably expressed itself in die-sinking and type-founding, young Bessemer practically lived for a time in the workshops which his father had set up in the village. Reaching London at the age of seventeen, with a brain teeming with original ideas, he evolved invention after invention, all more or less profitable. Thus he originated the first practical electroplating plant, and devised new and improved methods of embossing metals and other materials, and a machine for impressing internal revenue stamps on documents, thus preventing their fraudulent re-use, to the great loss of the revenue authorities. Bessemer devised perforated dies, by the use of which every stamp could be dated. This killed the dishonest practice in question, and saved the government nearly two thousand pounds a week.

Bessemer was to have been rewarded with a lucrative post, but governments, like individuals, sometimes forget their obligations, and he never made a cent out of his invention. Had he obtained the promised appointment he might have settled down to comfortable inertia, and the world would have waited in vain for its Bessemer steel. Better and cheaper steel would inevitably have come, but not when it did; and to-day we should have been short of thousands of miles of railroad track, of bridges, and other engineering undertakings.

We could not have had the new steel without another happy accident. Bessemer hit upon a secret process for manufacturing bronze powder and gold paint, which then sold at about thirty dollars a pound to printers and decorators. These powders were produced by hand at heavy cost in labor. Bessemer invented a machine which did the work more expeditiously and better. He was able to put it on the market at once at twenty dollars per pound, and he kept the secret to himself for a generation, at the end of which time he was selling at one-sixteenth of the price at which he had started. But for the bronze and gold powders he could never have obtained the capital necessary for his venture into the world of steel.

He was tempted into this field by the same events which attracted the attention of Lord Armstrong. The British army in the Crimea was furnished with utterly inadequate artillery. Bessemer set to work to rifle, not the cannon, but the projectile, but found that the metal of the existing guns was not strong enough to withstand the strain imposed. He at once began to seek a better material. Beyond experience with alloys in relation to other metals, he knew nothing of the subject, but the knowledge he did possess induced him to attempt the fusion of cast-iron with steel. He succeeded in getting his new metal, but it wholly lacked the properties desired.

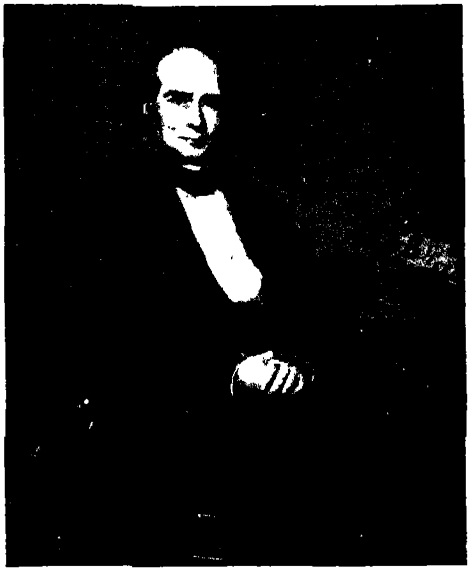
While experimenting, he chanced to discover, when melting gray pig-iron in a certain type of furnace, that some fragments of the iron, which had been exposed to the air-blast, lay on one side, clear of the fire, and remained solid, in spite of the

intense heat. At the end of a further half-hour, he found them in the same position. Taking an iron bar with the intention of pushing them into the fire, he found that they were merely the shells of decarbonized iron. The carbon had been burned out by the blast; atmospheric air alone was capable of converting molten cast-iron into malleable iron. He at once turned this accidental discovery to account by devising a furnace through which, when charged with molten pig-iron, air or steam under pressure could be blown.

After a succession of experiments he announced his success at a meeting of the British Association in 1856, when he read a paper on his process. This created a sensation in the scientific world, and iron-masters flocked to secure licenses to carry out his process. But the methods employed were not perfect; the licencees gave up the task in disgust, and for a time Bessemer and his process were under a cloud. Two years he labored in correcting the faults which had manifested themselves in the process, and succeeded in eliminating its weak points. But now the manufacturers, never very enthusiastic over the invasion of their market by a man who had much steel, and cheap, to offer in place of little, and costly, refused to touch his wares. In self-defense he was compelled to set up on his own account.

The first evidence of his success was conveyed to his rivals by the information that he was putting on the market high-grade steel at a hundred dollars a ton less than theirs. The Bessemer works at Sheffield were established in 1859, and within five years the process was in use throughout the steel-making countries of the world. From his works issued, in vast numbers, guns, boilers, steel plates, rails, girders, crank-shafts, weldless tires. His invention was quickly proving as important to the users of steel as Arkwright's had been to the manufacturers of cotton.

He effected improvements in the manufacture of glass and the polishing of lenses; and his plant for the cutting and polishing of diamonds, if it did not equal the work of Amsterdam, was very efficient. Sir Henry Bessemer died on March 15, 1898, leaving his record on the patent rolls of his country in the form of nearly six score inventions, and a generation incalculably enriched by the chief of them: cheap, high-grade steel



SIR HENRY BESSEMER

LOUIS BRAILLE

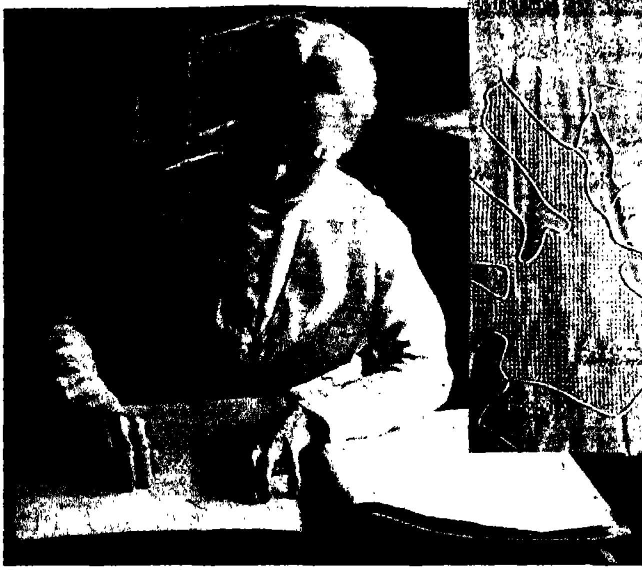
The Blind Helping the Blind to Read

LOUIS BRAILLE, the improver of printing for the blind, was born at Coupvray, near Paris, in January, 1809, and when three years of age lost his sight as the result of an accident. He was sent to a school for the blind in Paris founded by Valentin Haüy, who, in 1784, first printed raised letters for the blind.

He proved a brilliant pupil, and after completing his course was appointed a professor at the school, when only seventeen years of age. Now, Braille was the first to tell the world that all the systems of printing for the blind then in vogue were unsatisfactory from the standpoint of the person restricted to their use. Men gifted with sight had designed the letters for the blind, and, seeing the letters before them, they had not properly considered the question of touch, by which the blind read. The letter presenting simply a long, smooth outline in relief to the fingers is unsatisfactory.

Braille, who had studied every system in existence, probably drew his inspiration from Gall's serrated type, in which the surface of the letters was made up of minute points, instead of an unbroken line. Even there, however, the attempt was made as closely as possible to follow the outline of the ordinary letter with which those with sight were familiar. By none of the methods could the blind write. Before he was twenty Braille published the rudiments of his system. Five years more passed before he had perfected it. Not until two years after his death was it adopted for use in his old school.

An even greater value attaches to the system, however, in that it may be written by and for the blind as well as printed. The writer is supplied with a frame fitted either with a grooved or pitted bed. With a blunt awl he punches little pits in the paper through minute holes in a sliding guide hinged on the bed. He writes from right to left, but this reversal presents no practical difficulty as soon as the pupil has become accustomed to it. The reader reverses the paper, finds the characters raised in relief on the back, and reads, of course, from left to right.



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A BLIND WOMAN "READING" A WAR MAP

MAP FOR THE BLIND

This is a map of the Balkan States and Mediterranean. The rough portion of the map is water, the smooth land. The names of the countries have been added in black ink on this particular sheet to make it easier for those with sight to understand. The blind need only to run the fingers over the row of rough dots in order to read the descriptions.

The Braille system departs from all attempt to follow the outline of the ordinary letter. Each letter is made up of six dots, and each constitutes an arbitrary outline. The dots are arranged in two parallel columns. The heavy dots indicate the letter, and the remainder of the six dots are lightly indicated to establish the position and significance of the heavy dots. By varying the combinations of the dots, contractions of words and signs for punctuation are secured. The blind readily learn these letters, and read with striking facility.

Music can be written by this system without difficulty. Instrumental music is read with one hand, while the other is engaged upon the keys; then the other hand is brought to the manuscript while the notes for the second hand are mastered, and the whole is committed to memory. For vocal music the singer has both hands free to read the notation, and the expert can sing what in a seeing person we should call "at sight." Braille's highly valuable work for blind humanity was crowded into comparatively few years, for he died in Paris in 1852, when only forty-two.

THE KITCHEN AS A WORKSHOP

"Cookery Is Become an Art, a Noble Science." — *Anatomy of Melancholy*

HOW TO MAKE IT CONVENIENT AND PLEASING

THE kitchen is the workshop of the house and should therefore be planned with as much care as that of the carpenter or any other skilled artisan, both as regards the choice, kind and amount of equipment; and as regards the arrangement of the equipment for the greatest convenience. Inasmuch, also, as one woman at least spends here a great part of her day, the lighting, heating, ventilation and sanitation are very important to her health.

The kitchen, merely because it is a workshop, need not be ugly or uncomfortable. A suitable but attractive color scheme will make the work pleasanter because of the surroundings and will help to dispel that feeling of "blueness" or "nervous irritability" which comes with tired body and jagged nerves. A quiet corner with a comfortable chair where the worker can relax for a few moments when the opportunity occurs, will go far toward establishing that attitude of mind where she feels she can accomplish more with less fatigue than would otherwise be possible.

And since the cooking and cleaning have to be done, it behooves one to save strength and time and nerves by every possible device in tools and method; and by acquiring and utilizing scientific knowledge, which is the basis of the household operations, an added interest will be given to the most familiar and monotonous task, and its perpetual repetition will become less irksome.

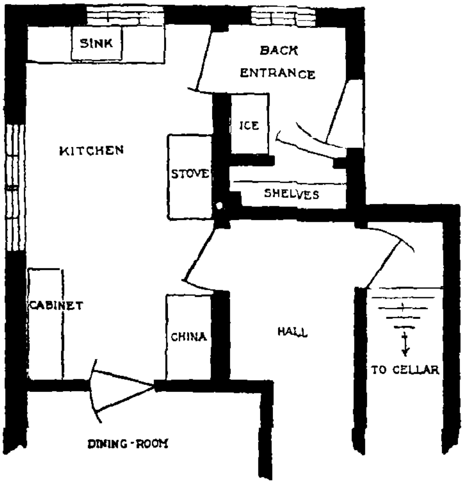
Ideally the kitchen is the place connected with food work only. It should not be used as a living room, dining room, wash-room, laundry, cloak-room or passage way to other parts of the house. It is more economical in the long run to separate these functions; nor is it hygienic to have soiled linen in a room where food is being prepared or to have dust and dirt from the street carried in on muddy shoes and disseminated, when it becomes dry, by continual passing to and fro. Moreover, the dust which is inevitably created during the process of food preparation will settle on everything in the vicinity, and the larger the kitchen, and the more there is in it, the more work results in the general cleaning which is part of the daily routine. The present tendency is to have a small, compact kitchen with laundry and storage separate; and where there is one large room which now fulfills several functions, it would be well to consider whether some rearrangement could be made which would result in less labor, more comfort, and more hygienic conditions (see plans on next page).

In planning or building a kitchen, it is of the greatest importance to see that it is in close proximity to the dining room, the food storage accommodation and the fuel supply — if coal or wood is used — and easily accessible to tradesmen and ice-man in order to obviate the necessity of carrying heavy loads some distance, or dripping ice across a spotless floor. It should also be accessible to the hall and front door without passing through the dining or living room, and yet so arranged that it is not possible for visitors entering the house to see into the kitchen, or for the odor of cooking food to escape into the hall.

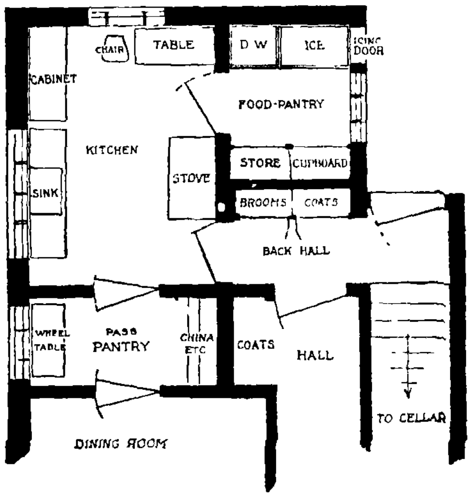
The most suitable aspect is north, northeast, or northwest so that, while being cool, the room may have good light. Two outside walls are desirable in order to get sufficient light and ventilation, and to keep down the temperature, so that the best location is on a corner of the house or in a wing. The windows should provide sufficient light to obviate the necessity for artificial light at any working-center during the day. Usually their total area should be at least twenty-five per cent of the total floor area and they should be so arranged as to allow of cross ventilation between themselves or between them and the outside door.

The position of the doors so as not to break up the available wall space is very important, and the direction in which they open makes a great difference to the comfort of the room. Swing doors between kitchen and pantry, and between pass-pantry and dining room are desirable.

The size of the kitchen depends somewhat on the size of the household and whether the room is utilized for food work only. It must be large enough to accommodate an extra worker on occasion. It depends also on what kind of fuel is being used, for with a coal range more heat is radiated into the room than from electricity or gas, and it must be somewhat fur-



A BADLY-PLANNED KITCHEN



THE SAME KITCHEN REARRANGED

It is better that the tops of the windows should not be more than one foot from the ceiling, as the hot air of the room rises and will tend to remain in any space above the top of the window. It is a good plan to have one opening extending to the top of the room. A small transom which tips and can be opened by a rope over a pulley could well be placed near the ceiling for the escape of the hot air if the windows are not high enough. Sash windows, easy to lower and raise, are better than casement windows for a kitchen, and if the distance from the floor to the bottom of the window is from three to four feet, there is room for a table or a sink beneath.

ther removed from the worker, and accommodation must also be made for its fuel. It has been found as a matter of practical experience that for an ordinary small household, the area of the kitchen and pass-pantry together should be about one hundred and fifty square feet if gas or electricity is used, and about two hundred square feet if coal is used. Eight feet is the minimum width for a kitchen, but the actual measurements must, of course, vary to fit into the plan of the remainder of the house. An approximately square kitchen is usually more convenient than a long, narrow one. In too small a kitchen the worker has no freedom of movement and soon becomes cramped.

Provision for storage

Although it is desirable to have the kitchen close to the dining room, it is preferable to separate them by a narrow pantry which will assist in cutting off the noise and odors from the kitchen. This will take the place of a china-cupboard in a smaller kitchen and is convenient for storing the dining room china, silver, linen, etc.; and here, bread may be cut and dishes filled ready for the dining room, many steps being thus saved if the bread, cake, etc., are kept here in suitable receptacles. This may also be a convenient place for a small refrigerator if there is no separate food-pantry in which to put it. For a large family, or for one living some distance from the stores, more food storage is required than can be provided by a refrigerator and a kitchen cupboard or cabinet. But in any case, if a coal range is used, the temperature of the kitchen will probably be such as to make it desirable to remove all food, and particularly the refrigerator, from the kitchen. Under these circumstances a cool food-pantry becomes a necessity. The pantry should be within easy access of the working-center of the kitchen. It serves as a store for the larger supplies, small quantities of which can then be kept in small containers at the working-center. The refrigerator can conveniently be placed on the outside wall and so be filled from the outside. Refrigerators can be purchased with a door in the side or back of the ice chamber and a corresponding opening can be made in the wall, fitted with a hinged window or door. In winter, this can be open and screened and the temperature of the refrigerator will be kept low without the use of ice. If the frame of the window or door is properly planned, the cold air will not come into the pantry or kitchen. There could also be a slide in this outside wall through which the milk bottles, etc., could be passed from or into a small cupboard fixed on the wall outside and fitted with a spring lock so that once the milk or parcel has been placed therein and the door closed, it can be opened only from the inside. This insures against theft.

Vegetables can be conveniently kept in a part of the cellar and if there is a suitable cupboard or shelf accommodation, this is a good place for the storage of canned goods. A dumb-waiter to the kitchen will facilitate the conveyance of materials to the work-table or sink, and is a real labor-saver. One trip a day to the cellar may then be enough.

Shelving for storage accommodation

Shelving accommodation should be graduated in height and depth in order to make the best of the available space. The height between the shelves should vary from seven to ten inches and the depth from back to front should be from five or six inches for small things, up to fifteen inches for larger containers, china, pans, etc., and each shelf should hold only one row of supplies. This eliminates moving a number of things to reach any given article. Shelves so arranged are easier to clean, and stock-taking is accomplished with a single glance. A good average depth for the open shelving in the pantry is from eight to ten inches. If deeper shelves have to be used for small things, they could be filled with a number of trays or boxes with sides about three inches high, and in these groups of similar things can be placed.

The pass-pantry should have, in addition to the china-cupboard, at least one shallow drawer subdivided for the silver, two or three shallow ones for table linen and one deep one for string, paper, etc.

In the cellar, trays with wire bottoms, which allow the air to circulate freely, and so prevent sweating or molding, are good for vegetable storage. Hinged fronts can be fixed. Or vegetable-baskets of galvanized wire, with sloping bottoms, make satisfactory and movable accommodation. A preserve-cupboard in the cellar should be cool, dark and dry, and the shelving adjusted to fit the bottles and jars.

Grouping of the permanent equipment

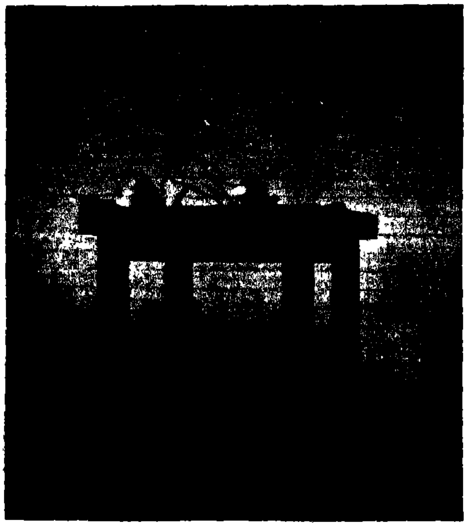
It has been calculated that the average American housewife walks between 500 and 800 miles per annum in preparing three meals a day in an inefficient kitchen.

This can often be reduced to at least half, if not more, by a logical and scientific arrangement of the equipment. In preparing a meal the various steps in the work are:

(*a*) Gathering together the material from the store-room or cupboard, the ice-box and the cellar, and placing them on the work-table. Hence, for convenience, the working-center should be as near as possible to the supplies.

(*b*) Preparation of the vegetables, fish, meat, etc. at the sink and the conveyance of them to the work-table.

(*c*) Mixing the ingredients.



A WHEEL-TABLE

(*d*) Cooking at the stove. And as the space between the work-table and the stove will probably have to be crossed several times, they should be as near as possible. The space between the work-table and the sink may only have to be traversed once or twice.

(*e*) Dishing-up. If a wheel-table, like that shown in the illustration, is brought near the stove, the finished dishes can be placed thereon as they are completed, and all taken at once to the dining room.

(*f*) The transfer of saucepans to the sink.

After the meal, the silver, glass, and cleaner china may be sorted as it is collected from the dining table and can be left at the sink, if there is one, in the pass-pantry, and the remainder wheeled to the sink in the kitchen. The sink should therefore be as close to the dining room door or pass-pantry as is convenient (see figure 2) and the contents of the wheel-table can be transferred straight into the sink or dish washer.

On examining these processes, we see there are three centers of work in the kitchen:

(*a*) Storage and working-center.

(*b*) Heat-center:

(*c*) Water-center.

And it is obvious that the working-center should be conveniently near the heat-center and not too far from the water-center, and that the water-center should be as near as possible to the dining room; and this arrangement holds whether the kitchen is one in an apartment, a small house or a large house. Rearrangement of equipment to reduce the distance to be many times traveled in a day is shown in figures 1 and 2, on a previous page.

Grouping of the movable equipment

Around each center should be grouped all those utensils and tools which are used at that center. At the work-center should be all the things required for mixing and preparing the dishes, such as bowls, flour-sifter, graters, egg-beater, forks, knives, spoons, measuring-cups, cake-tins, scales, rolling-pin and board, etc. Small quantities of food material in suitable containers may also be placed on shelves over the work-table or in larger cupboards or drawers below the working-surface. The table space should be from eight to twelve square feet. The pastry board can well be arranged to slide under the table-top.

A kitchen cabinet can take the place of such an arrangement. While either movable or built-in equipment can be made practicable and convenient, built-in equipment is perhaps easier to clean and better in appearance. With it there are no spaces behind or underneath to keep clean and there is no moving of heavy furniture. But once it is built it is difficult to move it to another part of the room to make the arrangements more efficient.

Above the sink should be a shelf or a small cupboard with sliding doors to hold the cleaning materials, soap-scrap jar, washing-soda, etc. The necessary brushes and mops can be hung above the sink. A small radial dryer is convenient for hanging up the wet dish-cloth, etc.

Choice of permanent equipment

The equipment of a kitchen should be chosen for efficiency as well as necessity and should consequently fill a need in such a way as to be economical of labor and material. Preference should therefore be given to those things which are easiest to keep clean and so remain sanitary throughout the period of their use. In selecting equipment, it is well to choose anything which saves the expenditure of bodily energy, such as a bread-mixer rather than a table made of expensive but good looking material; or a tool that eases a task that has to be performed very frequently, such as a potato-paring knife rather than a raisin-stoner. The housewife should, however, be sure that the tool or machine can be used with proper care for a reasonable length of time, no matter how little it costs, and the purchase should not be made without getting definite knowledge of how to operate the tool, for without such knowledge it may be so badly used that the efficiency is reduced and it may be put aside as unworkable or a failure, and the expenditure on it is not then a real investment. It is important to bear in mind that a labor-saving device or tool is not necessarily an expensive thing. It is simply the right tool for the particular work it is intended to do. The greatest of all labor-saving devices is the proper arrangement of the working-centers and the correct height of the working-surfaces.

Stoves

The choice of a stove depends of course on the fuel supply; and its size on the amount of work to be done. If of a standard make, the parts can be renewed easily as needed. A gas stove should always be provided with a hood and ventilating flue to remove the products of combustion from the kitchen and so keep the atmosphere reasonably comfortable. If coal or wood is used, labor will be saved by using the dumb-waiter to bring the supply of fuel from the basement; or if the supply is outside on the same level and near to the kitchen, it is well to have a fuel box with double-hinged cover built into the wall, which can be filled from the outside and emptied from within. Ashes may be emptied through an ash-chute into an air-tight metal can in the cellar, which could be emptied once a week. The chute passes from the ash compartment in the bottom of the stove through a hole in the floor to the metal can, and should be provided with a damper to prevent upward draught; it should also be flanged at the junction

CORRECT WORKING HEIGHTS
This table is too low for the worker on the right, but of correct height for the shorter person on the left

next the stove and there should be a free air space of two inches all around it where it passes through the floor — which space may be filled with concrete or have a metal collar. The container below must be protected so that no combustible material can be accidentally thrown against it.

Sinks

There are many materials used in the construction of sinks, but the one-piece enameled iron sink with a continuous high back is very satisfactory for ordinary careful use. The porcelain sink is the most satisfactory from a hygienic point of view, for the surface is smooth, easily cleaned, non-absorbent and non-rusting; but it is expensive. Good quality enamel

will also be smooth, easily cleaned, and non-absorbent as long as it is not chipped, but once the surface becomes cracked — and this may happen with a sharp blow — organic particles may accumulate in the cracks, the iron underneath will rust easily, and stains will be most difficult to remove.

Wooden sinks are quite unsanitary, as they gradually become slimy and rotten; slate and soapstone are smooth and inexpensive, but they gradually absorb grease; galvanized iron is cheap and durable and easy to keep clean and sanitary, but it easily rusts when once the coating is worn, and unless the front is protected by wood, the worker's apron may easily become stained. The size of the sink should be such that it will hold a dish-washing pan and a rinsing-pan comfortably. It should be shallow rather than deep. The drain outlet may be flat and provided with a grid with small openings to keep back the larger particles, yet not so fine that it hinders rapid drainage. If the outlet is sunken, it requires more care to clean.

Every sink, of course, should be provided with a strainer for the collection of larger food particles. The wall behind the sink, if the sink-back is not continuous, should be covered with some grease-proof and waterproof material beyond the height of the faucets. A piece of sheet zinc carefully fastened on the wall will serve this purpose, or the wall can be tiled or painted. Two drain-boards are desirable so that one can be used for piling the soiled dishes and the other for the washed dishes. If there is room for only one, the wheel tray can be used for the reception of the clean dishes. The boards may be of hardwood, — ash, maple, oak, or elm. They may be grooved to carry off the water and have a raised edge and slope one inch toward the sink. To make them waterproof, they can be oiled. This is more satisfactory than varnished or unfinished wood. The wood must be thick and heavy enough to avoid warping and splitting through the continual wetting to which it is subjected on one side. Enameled iron drain-boards are noisy as well as hard on the dishes. The sink should be supported from the wall at a proper height and the plumbing underneath must be open so that the trap is easily accessible. Drawers and cupboards do not allow of thorough cleaning under the sink. The space under one drain-board can be utilized for the dish-washing machine or for the hooks on which to hang the dish-pans; under the other drain-board can be a drawer for the kitchen cloths, coarse apron, etc., and a cupboard for larger equipment such as the freezer, bread-mixer, etc.

Tables and table tops

Firmness is an important consideration in choosing any working-surface. The material of which the tables are made must be smooth, non-absorbent, unstainable, not affected by acids or alkalies, easily cleaned, and must wear well. Wooden tops require constant scrubbing unless they are varnished or oiled, and as these surfaces are easily injured they are difficult to keep in good condition. The wooden surface can be covered by oilcloth which can be renewed frequently for a small cost; or it can be covered with sheet zinc which will wear well and clean easily, but this is affected by acids and alkalies and is therefore not particularly good for contact with food. One of the newest tops is corkoleum which appears to be satisfactory. Glass tops are sanitary but may crack when a hot dish is set on them. Enamel tops, like sinks, are sanitary as long as they are not chipped, but they will not stand cutting blows, neither can the meat grinder, etc., be screwed on them with safety; and the cheaper enamels may be roughened by the use of acids. Possibly the better quality enamels, such as are used in the manufacture of gas stoves, will meet all the requirements, but they should be guaranteed before purchase.

Height of working-surfaces

Much energy is wasted by the harmful pose of the body necessitated by the working-surfaces being too low. The right pose of the body is the first great essential in physical economy. Nature's bending

places are at the hip joints and the knees, and when we ignore them and bend the back, the lungs are compressed, the digestion is enfeebled, the shoulders and back gradually acquire a permanent roundness, and the body becomes heavy and set and ages prematurely. Even when bending from the hips in the right way, further strain is avoided by having the surfaces at the right height. The top of the table, the bottom of the kitchen sink and the bottom and sides of the wash-tub are the working-surfaces. Unfortunately, these are frequently all too low for most workers. For a worker of medium height, about five feet six inches, the table top should be thirty-three to thirty-eight inches for standing work and twenty-eight to thirty-one inches for sitting work, and the kitchen sink thirty-four to forty inches from the floor to the top. For ironing, kneading, etc., a slightly lower surface is better to allow for the extra pressure required and a table which could be lowered or raised at will for different tasks would be convenient in any kitchen. It is comparatively easy to raise the height of a stove or table with blocks, but the sink is a more expensive item and should be fixed at a suitable height when it is installed. It is easier and less expensive of energy for a short worker to stand on a stool or platform large enough to allow her to step about without stepping off, than for a tall worker to bend over continually; and such an arrangement enables children to take a share in the work without fatigue of overreaching. It is far better therefore to have all the permanent fixtures too high rather than to have them too low.

The choice of the material for kitchen utensils will be discussed in a subsequent chapter.

In choosing china or earthenware, and in fact all vessels, good plain shapes are preferable to fancy ones. Avoid jugs or pitchers, teapots, etc., with a neck so narrow that the hand cannot be put inside to wash and wipe them. Tea-cups and saucers of a fluted pattern, handles with irregular surfaces and "nubbles" all hold the dust.

Plain glass is always easier to care for than elaborately cut glass. Knives, forks and spoons may be plain or elaborate, but the plain ones are much less trouble to keep clean and are usually in better taste than the highly ornamented ones.

Floors and walls

All surfaces in the kitchen, floors, walls and ceiling, should be plain and free from cracks, ridges, moldings and ornamentation. They should be non-absorbent, easy to clean and inexpensive to renew. All corners should be rounded to avoid the

A GOOD WORKING POSITION AT THE WASH-TUB

accumulation of dust and dirt. If the wooden floor is unfinished, it can be scrubbed frequently, but softwoods easily become soft and splintered with constant wetting. Various floor finishes are discussed in Chapter III. Carpets and matting are unsuitable as they hold the dust and dirt. Linoleum is durable, soft to the feet, and easily kept clean, but it must be laid down properly. It can be nailed directly to the wood floor, but a better method is to cement it firmly over a lining of builders' deadening felt-paper. The underfelt takes up the expansion and contraction of the wood and acts as a cushion,

deadening sound and adding to the warmth and comfort of the floor and making it soft to stand on. The felt is laid the short way of the floor, the quarter-round molding being first removed. Linoleum-paste is applied to the under surface of the felt, which is then rolled and pressed till it adheres. The lengths of linoleum are then laid in the other direction of the room, being pasted on to the felt along the middle of the strips, the edges and seams being fastened down to a distance of about six inches with linoleum-cement which makes the whole water-tight. The linoleum is then rolled and pressed down well for twenty-four hours and the molding is replaced so that the linoleum can expand under it. This method of fixing linoleum applies to wood floors and concrete floors, but the concrete floors should first be waterproofed if necessary, and the cracks filled in with plaster of Paris. Linoleum can be waxed or varnished. It should be washed as infrequently as possible, then with pure soap and tepid water. Washing soda and lye are destructive. Finally it may be rubbed with a soft cloth to renew the polish.

A satisfactory surface for walls and ceiling is one that will not peel or crack and can be easily cleaned and cheaply renewed. Paint is generally satisfactory for the walls and ceiling. An excellent finish for a kitchen wall is smooth, hard plaster, coated with two coats of enamel oil paint. This can be sponged clean. Paper is easily loosened from the walls and collects dust and dirt readily.

In conclusion, equipment which is necessary and convenient should be supplied to the kitchen, and that which is used most frequently and which will save heavy labor should first be installed. The scientific placing of equipment will reduce the number of steps and consequently the time and energy required for kitchen tasks

Graham Photo Co

GROUP OF HOUSES ARRANGED ABOUT A COURT

The garden unifies and greatly enhances the general appearance of this group of Los Angeles houses which is strongly Italian in character.

UNFOLDING OF THE UNIVERSE

The Static and Genetic Views of Nature Compared — Permanence or Change; Which is Nature's Ruling Law?

HYPOTHESES GUIDING SCIENTIFIC RESEARCH

WE have surveyed the outwardness and the inwardness of the universe; its unity and persistence have impressed themselves on our minds, but at the same time we have also seen that the earth and the heavens have not always been as they are today. The earth and all the planets are ever rushing about the sun and the solar system as a whole is moving rapidly through space, so that even when we complete the yearly journey in our orbit we do not return to the same starting point (we are in fact today more than 300,000,000 miles from where we were at this time last year). Nor is there any indication that the sun is traveling in an orbit rather than in a straight line through space, so that no matter how many ages the world may last it is not to be expected that it will ever occupy the same position twice. Not only are we moving in space, but the physical conditions of the earth are constantly changing: the shores are being washed away here and built up there; the mountains are being worn down by rain and wind and the valleys filled up with the detritus; the sun is pouring forth untold quantities of energy into stellar space and receiving scarcely any in return. Activity and change are essential characteristics of all created life: from microscopic cells the individual develops into expanded maturity, not indeed to remain thus in its perfect stature but to decline and die and be resolved once more into its elements; generation succeeds generation and thus only does the race persist. There are therefore both change and persistence in nature, and we must now inquire into the relationship of these two characteristics.

There are, in this regard, two opposed views of things, which we may term the "static" and the "genetic" views. The static view — which in English is the "standing" view — stresses persistence and sees things on the whole in a stationary condition, recognizing indeed the constant changes that are so evident, but deeming these changes to constitute a more or less brief rhythm, which sooner or later restores things to their former state. The genetic view, at least in its extreme form, denies any rhythm whatever in the history of the universe; according to it change, and not persistence, is the all embracing law of nature. It sees all things forever impelled from within or from below, in such fashion that the present is always novel and unique, the child of the past and the parent of the future; but the child is never quite like its parent, and each generation adds new differences until the far off descendants are utterly unlike their remote ancestors. Let us apply these two views a little more in detail to some of the main features of the universe in which we are more especially engaged in this section of our work. Consider the solar system: what is its history?

The static view says that the solar system was from the beginning just what it is now, namely a family of planets and satellites, dependent on the sun from which they receive their light and heat and by which they are governed in their motions. And if it be asked what is meant by the phrase "in the beginning" the answer is that the "beginning" means when God by his infinite power brought the universe into being and set the sun and moon and planets in their present order and arrangement.

On the other hand the genetic view, which is known as "the theory of cosmic evolution," holds that in the beginning the solar system was a great diffused mass of matter which had, or soon acquired, a state of slow rotation; this mass was subject to the law of gravitation in accordance with which it slowly shrank by virtue of the mutual attraction of all its parts, whilst its rate of rotation increased, in conformity with the principle of the conservation of momentum, until the outer portion became subject to a centrifugal force greater than the attractive force of gravitation and was hence unable to cling any longer to the more condensed central nucleus and separated from it in the form of a ring of matter which later on gathered together into a great globe, thus constituting the most distant of the planets; as further shrinkage in the original nebulous mass continued new rings separated from it and the matter of each ring collected together to form the successive planets of which the earth is one; each of these planets in its early history followed a similar process of condensation and increasing rotational motion; most of them cast off one or more subsidiary rings which formed the moons or satellites of the planets which observation now reveals to us. If it is asked of the supporters of this theory what is meant by the phrase "in the beginning" the answer is that the "beginning" merely means the simplest stage of development with which we can, with any fair prospect of successful explanation, begin our consideration of the series of transformations leading up to the present condition of things. As to the question whence came the original matter of the nebula or diffused mass, and what determined the original distribution of energy within it, that falls outside the scope of the theory which concerns itself with the transformation and not the origin of the nebula.

Turning now to another great feature of the universe, namely that of organic nature, we see around us a wonderful profusion of plant and animal life, existing in countless different species of both animals and plants.

Here again, if we should ask whence came all these different forms of life, we find two opposed views. The static view, or as it is called in this connection "the theory of special creation," holds that God after having created the earth, created or formed by direct divine action a few individuals of each of the natural species of plants and animals, and that all the living creatures now existing are descended without any essential modification from the original members of their respective species. The genetic view, or as it is called in this connection "the theory of organic evolution," holds that all the multitudinous forms of life that we now see on the earth are derived from a single form or at least a few forms that appeared on the earth when, by a process of cosmic evolution, it had reached a stage favorable to the support of life If we ask how life first appeared on the earth, we are answered that as far as organic evolution goes no answer can be given to this question, the proper domain of organic evolution being restricted to tracing not the origin of life but the various steps by which the first form or forms of life developed into the great variety of forms now existing in the world today.

This much simplified statement of the two views refers properly to their status during the period prior to the development of the auxiliary science of palæontology which opened up new vistas and supplied the defenders of geological and organic evolution with their strongest arguments; hence a brief account of the rise and progress of the modern doctrine of evolution will be very helpful and almost necessary before we try to weigh the merits of the two opposed views under discussion.

Historically, then, the doctrine of evolution in the heavens, or cosmic evolution, was the first in modern times to win anything like serious consideration. It was set forth in 1746 by Thomas Wright, who supposed the starry heavens constituting the Milky Way to be made up of a vast number of systems of stars bound together by the force of gravitation and distributed in a great double ring rotating about an axis perpendicular to the plane of the ring.

Wright's book, which dealt mainly with the evolution of the sidereal system as a whole, came to the notice of the German philosopher Immanuel Kant some five years after its publication; it interested him deeply, and he set himself to the task of explaining on purely dynamical principles the genesis of the solar system from a vast mass of uniformly distributed particles. He published the results of his speculations in his "*Allgemeine Naturgeschichte*" in 1755; and in 1796 there appeared Laplace's improvement on the theory, which is known as "the nebular hypothesis." At about the same time biologists in France and Germany suggested that in the organic domain the theory of special creation must yield to a theory of the origin of species by "descent with modification." Up to the middle of the nineteenth century neither of these doctrines found any wide acceptance among scientific men, and the reason in each case is a highly interesting one. So far as concerns the nebular hypothesis of the origin of the solar system suggested by Kant and elaborated by Laplace, advances in telescopic astronomy had sadly discounted it. The newest and largest instruments had succeeded in penetrating space to such extent that many objects formerly supposed to be nebulæ turned out not to be nebulæ at all, but closely aggregated clusters of stars. The inference was that further developments of the telescope would enable astronomers to resolve more supposed nebulæ into star clusters, and that, if we could only see clearly enough, there would be no nebulæ left, but only more or less distant and closely clustered groups of stars. Plainly the nebular hypothesis breaks down, as far as observational foundation goes, if no such things as nebulæ can be found in the heavens. There was at that time no means of determining whether an apparent nebula was really such, or only seemed such on account of its vast distance; for it was not until August 29, 1864, that Sir William Huggins, by means of that marvelous instrument of cosmical investigation, the spectroscope, definitely demonstrated that there are true nebulæ in the firmament.

If the theory of cosmic evolution had been in a bad way, no better could be said for that of organic evolution. Its founder and most distinguished advocate, the French naturalist Lamarck, presented a theory of the process of organic transformation of species which was inadequate and unsatisfactory Its truth was very doubtful, and it could explain only a small fraction of the facts even if it were true.

KANT, AUTHOR OF THE NEBULAR THEORY

It was Immanuel Kant, the German philosopher, who founded the theory of the solar system having been derived from a nebula, or fire-mist, yielding planets in the process, as our colored plate inserted at page 456 suggests.

In one department, however, the case of evolution seemed more promising, namely in that of geological evolution, that is, the evolution of the surface of the earth as distinguished from that of the earth as a whole, or as a planet of the solar system. The British geologist Sir Charles Lyell gave very solid reasons for believing that the history of the earth's crust was evolutionary, or in the word of the period, "*uniformitarian*," as contrasted with the generally accepted *catastrophic* view, which attributed the several layers of the crust, and their various de-

posits of fossils, to a succession of catastrophes, by which the surface of the earth was racked and torn on a tremendous scale, and by which the existing forms of life were destroyed, followed in each case by the special creation of new forms of life: those, namely, which are peculiar to the various geological strata. Lyell, however, while holding throughout his long scientific career to the evolution of the crust of the earth, did not accept the doctrine of organic evolution until towards the close of his life and under the influence of Darwin.

How the theory of cosmic evolution came to be generally accepted

It will be noticed that the theory of evolution as here outlined is properly a scientific hypothesis brought forward by certain leaders of scientific thought for the purpose of explaining a vast mass of observational facts and of coördinating these facts by referring them to their efficient causes as far as these could be discovered. The theory was defended by its protagonists on scientific grounds and likewise opposed by its critics on scientific grounds; and up to the middle of the last century the scientific opponents of the theory practically held the field. But in the second half of the century the scientific aspect of the conflict was almost completely reversed The discovery of true nebulæ by means of the spectroscope removed a fundamental difficulty in the way of cosmic evolution; mathematical and astrophysical investigations, while showing the untenableness of the details of the Kantian and Laplacian forms of the hypothesis, led the way to the formulation of more workable systems of stellar and planetary development, and swung the scientific world, almost without exception, into the ranks of the upholders of cosmic evolution. Again, a more extensive study and deeper appreciation of the very potent action of air and water on the surface of the earth, coupled with a better understanding of the processes of slow upheaval and subsidence of very large areas of land, firmly established geological evolution as the groundwork of general geology.

Finally the work of Darwin and Wallace on the origin of species gave a tremendous impetus and wide popularity to the theory of organic evolution; and despite the fact that their views as to the proximate factors and the modes of organic development are now known to be defective and in many points contrary to established facts of observation, the main doctrine that the present species of plants and animals are genetically descended from more simple primitive forms became, and still remains, the dominant guiding hypothesis of scientific biological research.

The attempt to make of evolution a new "religion of nature"

So much for the scientific aspects of evolution in the material and organic domain But there is another or, rather, there are several other aspects of evolution which should also be noticed before we try to form our judgment of its merits or proceed in the study of the universe which we have undertaken. A rather large class of writers, going beyond the domain of science, sought to extend the theory of evolution so as to make of it not a scientific hypothesis but an all-inclusive philosophic system; and a fair proportion of these authors went still further and endeavored so to exalt the theory as to endow it with the dignity of a new "religion of nature," or else to substitute it in place of all religion Perhaps the most influential of those who in the last century sought to make of evolution a universal philosophic system was Herbert Spencer; while among those who set it up in opposition to the Christian religion and to all belief in a personal Creator none probably was more widely known than Ernst Haeckel, whose writings too frequently exhibit evident marks of the partisan controversialist more eager to score a victory over his adversaries than to uphold the purity of scientific truth. On the other hand the theory has been combated by some on religious rather than scientific grounds, because of their persuasion that it was either contrary to Sacred Scripture or to due respect towards God as the immediate author of the universe.

AN ARTIST'S VISUALIZATION OF AN INTERMEDIATE STAGE OF THE SOLAR SYSTEM ACCORDING TO THE NEBULAR HYPOTHESIS

Out of a fiery vortex such as this picture suggests, the earth and the entire solar system was, according to Laplace's famous nebular hypothesis, evolved into its present stable condition. Scores of thousands of spiral nebulæ which bear a resemblance to such a fiery vortex have been discovered and many of them have been photographed through the great telescopes of the world's most famous observatories. Since the outermost known planet Neptune is almost three thousand million miles from the sun, any nebula large enough to evolve into the solar system must have been at one time six thousand million miles or more in diameter, or seven hundred and fifty thousand [illegible]

How the word "evolution" is used in several different senses

What then are we, not as mere scientific specialists, but as men with all the broad interests and aspirations of human nature, to think of evolution?

From what has already been said above it is clear that the word "evolution" is used in many different senses, and hence we cannot respond to the question with a simple categorical approval or condemnation. For clearness' sake and for precision we must therefore divide our answer into several parts according as the question is asked with regard to the different senses of the word.

"Evolution" then is sometimes taken to mean Darwin's theory of natural selection; this is only a particular form of explanation of the mode of organic evolution, an explanation which we have said has been discredited by later scientific research. It should be called not "evolution" but "Darwinism"; and with this particular form of evolutionary explanation we are not here concerned.

Ignorant and grotesque, unscientific and repugnant application of the term

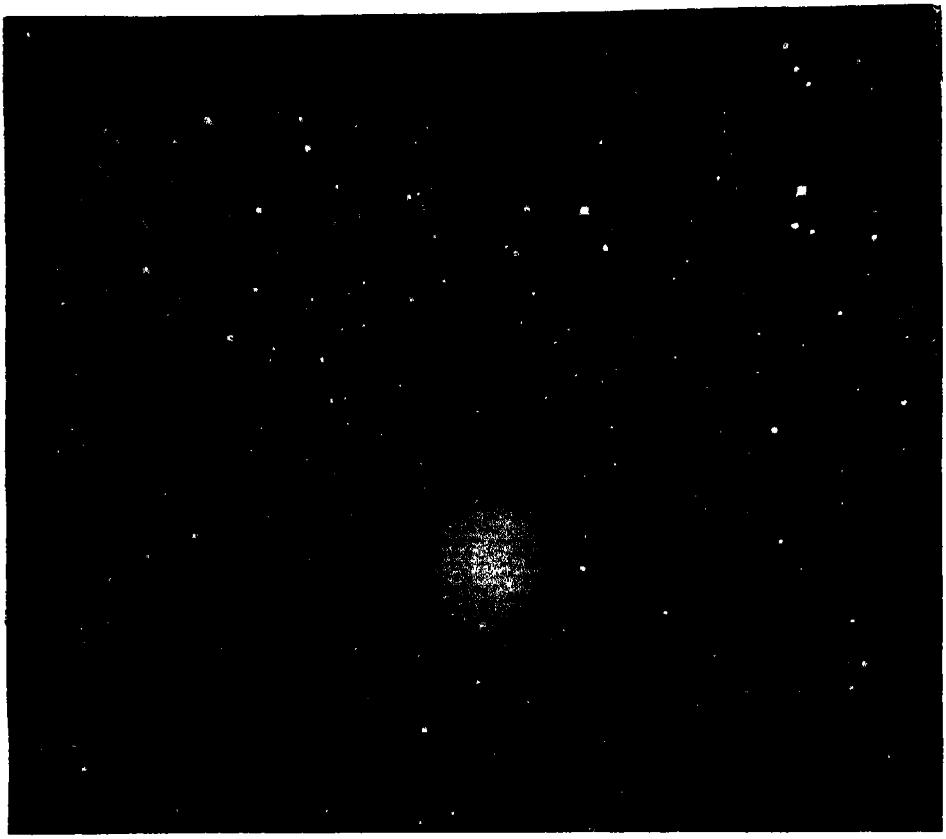
Secondly "evolution" is often used, especially by popular writers, to mean the descent of man from brute ancestors; in its crudest form it states that man is nothing but a highly developed chimpanzee, and used in this sense it deserves to be called ignorant and grotesque, to say the least. In less crude form it asserts that man's body was developed through many generations from brute ancestors, and leaves open the question as to how and whence came the principle of those higher operations, intellectual and moral, which mark him off so unmistakably from the domain of brute animals. Considering it in this restricted sense, we may say that there does not appear any *a priori* impossibility of such a descent of man as to his bodily structure. The question of fact, however, cannot be answered positively from a consideration of its possibility, and must be settled, as far as science can settle it, by weighing the whole evidence that comes to hand.

Now the sum of the evidence that we have in hand does not settle the question of fact with finality; that evidence is detailed and discussed in other chapters of this work; the question, especially when taken, as it ultimately must be, in connection with man's spiritual activities is clearly too important and too intricate for summary settlement and we therefore leave it to that portion of the work which treats directly with man himself.

Thirdly "evolution," as propounded by the monistic school which follows the lead of Haeckel, is set up as the ultimate source and the universal cause of all phenomena and the self-sufficient explanation of all seeming order and progress in the world, thus doing away, as they claim, with the necessity for admitting the existence of an intelligent, self-existent Creator as the First Cause and the Designer of the universe. Taken in this sense it is clearly unscientific as well as repugnant to the intellectual convictions and the moral aspirations and experiences of the bulk of mankind; it is likewise philosophically false, since it really violates the principle of causality, which demands with absolute necessity a sufficient ultimate cause for every effect that is produced, and among these effects must be counted the order of the universe and the myriad examples of the adaptation of means not only to present but also to future ends. In the distorted materialistic or pantheistic form of universal evolution this order and adaptation have no true explanation whatever, nor have any of the spiritual and moral activities of man. It is chiefly because of such extravagant tendencies on the part of too many evolutionists that many people mistakenly suspect every theory of evolution of being fraught with the utmost peril to religion and to all those things which, in the last analysis, are really worth while.

The strict sense in which we understand and shall use "evolution"

Fourthly "evolution" is taken in a strict sense, the sense in which we understand it in these chapters, as a scientific hypothesis which asserts that the present order of the universe is the outcome of a



THE BEAUTIFUL CORE OF THE GREAT NEBULA OF ANDROMEDA

According to the nebular hypothesis it was from a mass of glowing gas such as this that our solar system evolved, and from which even now new stars may be evolving. This photograph was taken at the Yerkes, that on the opposite page at the Lick Observatory

process of orderly change from a different and much simpler order, which change is brought about by the natural operation of forces and tendencies inherent in the definite distribution of substance and energy of the original matter of the universe, as far as cosmic and geologic evolution is concerned, and in the original simple forms of life, as far as organic evolution is concerned. In other words evolution is a statement to the effect that the universe was not made *as it is* by the direct creative act of an external cause but having received existence from some sufficient cause, has unfolded from its original state in virtue of the natural interaction of finite causes internal to itself. The scientific hypothesis of evolution is therefore directly opposed to the doctrine of "special creation." Are we then to think that it is likewise opposed to the doctrine of the ultimate and essential dependence of the universe both for its existence and its perpetual activity, on an external self-existent and personal Creator? Unfortunately many people, including both scientists and popular writers along with their disciples, teach or believe such an opposition. They tend to make a fetish of evolution and to look on it as a true cause — a cause which having now been discovered disposes forever of the belief in a First Cause distinct from the sum total of the visible elements that go to make up the world. But this presentation, or rather misrepresentation, of the doctrine of evolution is thoroughly vicious and thoroughly unscientific, because it is part of true science to know its own limitations and the limitations of the finite causes with which

THE NEBULA OF ORION: A VAST SHAPELESS MASS OF GLOWING MATTER

The earth sweeps round the sun in a circle not less than 18[illegible] million miles across, and if we could imagine a globe as vast as this, and then imagine a million of these globes rolled into one, this incredible vastness would still be smaller than the nebula of Orion

it deals and hence to recognize that it does not and cannot give the ultimate explanation of even the simplest possible phenomenon. It treats of the proximate causes of things and of their orderly operations, but surely no succession of orderly operations and no series of proximate causes each dependent on an equally dependent antecedent can possibly be taken as the ultimate explanation of reality. That ultimate explanation must necessarily be sought in something outside the limited and ever-changing beings which at any moment constitute the visible universe. That unlimited unchangeable Ultimate Cause, the source of all finite reality, the Author of all the power and order and beauty of the universe, can be none other than God. And if for the doctrine of special creation one substitutes the doctrine of evolution as defined and circumscribed above, he is neither denying nor minimizing either the dependence of the universe on its First Cause or the power and wisdom of that Cause; for if God, having produced the original universe by a creative act of His will, so endowed it with power that it could, through the operation of the laws implanted in it by Him, perpetually show forth new and increasingly wonderful manifestations of perfection, His power and wisdom are thereby not denied but only the more exalted; for, as a great saint and philosopher has said, "the potency of a cause is the greater, the more remote the effects to which it extends." And it is a principle of sound philosophy that "God does not interfere directly with the natural order, where secondary causes suffice to produce

the intended effect." There is therefore no solid reason for the existence of any conflict between true science and belief in God, and the scientific evolutionist may conclude with a noted German biologist that "the history of the animal and vegetable kingdoms on our planet is, as it were, a versicle in a volume of a million pages in which the natural development of the cosmos is described, and upon whose title page is written: 'In the beginning God created the heaven and earth.'" We acknowledge that to many scientists the very mention of the name of God, as the Author of the universe, in a work that purports to be scientific is irritating and distasteful; fortunately this work is not written either for the instruction or the delectation of the scientists; it is meant to appeal to that large and growing class of educated men and women who view life and truth with a broader and better balanced outlook than those scientific specialists who seem to think that nothing is knowable or real which cannot be focused within the field of a microscope or a telescope. Specialization has its advantages and we gratefully accept all the really established facts and laws that are the fruit of the marvelous devotion of the specialists to the cultivation of their chosen fields; but despite our admiration of their skill and our appreciation of their contributions to positive knowledge we see no need of circumscribing our views of nature, or our discussion of it, by the limits of any special branch of research. Science deals with the handiwork of God and hence the more perfect the knowledge it can supply us of the operations and laws of nature the better it enables us to know the Author of nature, even though He is outside its direct domain. So thought saints and sages, philosophers and scientists; so thought at one time Darwin, when in the concluding lines of his "Origin of Species" he wrote: "There is grandeur in this view of life, with its several powers, having been originally breathed by the Creator into a few forms or into one; and that, while this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and wonderful have been, and are being evolved." So also, more firmly and unfalteringly, thought the founder of organic evolution, who lost nothing as a scientist by being able to see those truths that transcend science, but are nevertheless necessary to the full understanding of any complete system of cosmogony, the study of which may well lead us, as it led Lamarck, to understand better the perfections of the Creator which are so admirably reflected in His creation, and to agree with that eminent scientist's conclusion: "Of the Supreme Being, in a word God, to whom all infinitude is seen to belong, man has thus conceived an idea, which though indirect, is sound, and which necessarily follows from what he observes. In the same manner he has formed another idea equally solid, namely of the boundless power of this Being, suggested by the consideration of His works. . . ."

We may therefore accept evolution as a scientific hypothesis without falling into the snares and errors of either the materialist or the atheist, whose conclusions instead of being supported by science are on the contrary excluded by it; because science demands as a necessary prerequisite for its investigations the solid foundation of a First Cause whose infinite perfections can ultimately account for all the perfections and powers of the finite proximate causes of the events in the universe which science observes and seeks to explain.

There is one point that still needs presentation before we complete this preliminary survey of the various views of nature outlined above. Is evolution merely a scientific hypothesis or is it also a definitely established fact? Evolution as defined above is not and cannot be a fact of observation; all the events that have come under the observation of man have been described by a professor of history as "only a few of the front carriages, and probably the least wonderful, in the van of an interminable procession." And from the very nature of the case no man could have been present at the evolution of the solar system; no man could have noted and appraised the rise and progress of the myriad stages of develop-

ment that are supposed to have led up to the present species of the vegetable and animal domain; nor can ordinary historic records be of avail here since the present species are so stable as not to have changed to any great degree since the dawn of history. The hypothesis then must be proved, if proved it can be, by other means than direct observation. These means may be divided into three main classes:

1. We can seek to discover in the heavens examples of heavenly bodies of different formation and structure and condition, and so related that they can be arranged in a series of stages of development corresponding to those stages which our mathematical, physical and chemical investigations show a nebula must, or at least might, actually pass through in changing from the initial nebulous condition to that of a central sun surrounded by dependent planets similar to our own. If we are successful in this search then we have circumstantial evidence though not rigorous demonstration of the evolutionary origin of the solar system. With regard to cosmic evolution this is what has been done by scientists during the last century and a half; and therefore we may say that cosmic evolution gives a truly probable but not an absolutely certain scientific statement of the proximate origin of our solar system. The account of these investigations and the presentation of the evidence thus secured will here be found throughout the chapters on "The Universe."

2. Next we may examine the actual working of the laws of nature along definite lines and take it for granted that they apply to all past ages on the principle that the laws of nature are in themselves immutable; having thus examined these laws and their operations we may start with the present condition of the earth, say, and from that present state work backwards to more and more remote stages of the planet as far as our own insight and knowledge of the laws allow us; this has been done for geologic evolution and gives to that department of the evolutionary hypothesis a greater degree of probability than we seem able to obtain for the doctrine of cosmic evolution.

This evidence and these investigations are here given in the chapters on "The Earth."

3. With the two means given above may be combined, especially in the domain of organic nature, a third instrument of investigation, namely experimentation in evolution by which we seek to find out how and to what extent living things are subject to structural change through change of environment, through change of functional activity, through selective breeding both in pure line series and by hybridization. By all these means and others which require the assistance of the sciences of biology and zoölogy in all their branches and of other sciences, especially of that part of geology called "palæontology," which deals with the fossil records of previous ages, the most intense and persistent study has been made of organic evolution with the result that today it is looked on as the very foundation of all biological investigations, though it must be confessed that the leading biologists and zoölogists of the world can come to no agreement as to the factors that may induce and determine the transition from one systematic species to another. Hence while accepting organic evolution as a very serviceable scientific hypothesis, we cannot refrain from viewing as sheer dogmatism the assertion of some scientists that universal evolution in all its branches is an absolutely established fact of nature, the denial or doubt of which inevitably marks him who makes or entertains it as unworthy of the name of scientist or lover of truth. Neither science nor truth need the support of such dogmatism nor do they gain aught by it.

In this work we endeavor to give all the evidence available in the matter and to draw such conclusions as are justified by that evidence: of these conclusions some are certain, others are only probable, and they should therefore be accepted by the reader with that degree of intellectual adhesion which the evidence itself logically demands. He will be the truest scientist who can best estimate the real worth and weight of that evidence, and without prejudice or rancor hold fast to that which is proved.

CURIOUS EFFECTS OF EARTHQUAKES

San Francisco earthquake of 1906: the shearing effects on a pier at Inverness, on the west coast of Tomales Bay. Notice how the end of the pier was displaced about 20 feet toward the N. NW.

Formosa earthquake of 1906: shear of the Taihorin-Baishiko Road; the foreground (southern side) sank 6 feet and was displaced 6 feet westwards. The two signs (X) mark the former continuation of the road,

HOW THE OLD EARTH TREMBLES

How Earthquakes are Foreseen and their Effects Mitigated

THE MARVELS OF THE SEISMOGRAPH RECORDS

VIOLENT earthquakes, which are among the most striking of natural phenomena and whose destructive effects are much more far-reaching than those of volcanic eruptions, have often been regarded as the miraculous manifestations of divine power and are mentioned in the Bible and other ancient books. The earliest earthquake recorded dates back to about 4100 B.C., when a chasm opened in the earth near the city of Bubastis, in Lower Egypt, and many persons perished. In Japan, a classical land of seismic and volcanic disturbances, earthquakes naturally made early a profound impression on the people and, in spite of superstitious fears, often served as a stimulus to their courage in times of danger. Thus, on the occasion of the great shocks of December 23 and 24, 1854, the year in which the treaty with Commodore Perry was concluded, the feudal lord of Tosa issued a proclamation enjoining his subjects to take these disasters as censures from heaven and to do their utmost in guiding the empire through the difficult epoch of internal troubles and foreign complications. Quite characteristic was the conduct of the soldiers stationed in the city of Kagi on the occasion of the great Formosa earthquake of March 17, 1906. At the moment of the shock, $6^{h.}$ $42^{m.}$ in the morning, the soldiers were washing outside the barracks. They at once rushed into their rooms and out again with rifles in hand, before the fall of the building, not forgetting their duty even amid the terrors of the violent shock. The same spirit was observed also by the *samurais* of the old times, and to such degree that after the destructive Yedo (Tokyo) earthquakes of 1649 and 1703, the Shogunate government issued rescripts ordering the military officials to escape out of doors, in case of a severe shock, and not run the risk of unnecessary injury or death.

An earthquake is caused by the growth of a weak spot within the earth's crust, finally resulting in some violent underground disturbance such as the formation or extension of a crack, the collapse of the roof or sides of a cavity, sudden expansion of steam and gases, the dislocation of the strata, etc. The phenomenon of an earthquake itself consists in the wave motion propagated through the ground from the origin of disturbance.

It is true that a volcanic country, like Japan or Italy, taken as a whole, is often visited by earthquakes. But the immediate vicinity of a big volcano, like, for instance, Asama or Vesuvius, is never shaken by a great destructive shock, the volcanic activity serving as a sort of safety valve, which prevents the local accumulation of subterranean stress. Although not related as cause and effect, volcanic and seismic manifestations may tend to become simultaneously active at different places. Thus, the great eruption of Vesuvius in April, 1906, began on the 7th and ended on the 13th; on the next day a violent shock occurred in Formosa, followed four days after by the San Francisco earthquake.

Seismic (*i.e.* earthquake) disturbances are the results of the underground stress going on for a considerable length of time; and a great shock in a seismic region occurs only once in several years or even several centuries. When, therefore, an earthquake is about to occur, the earth's crust

in the vicinity is in a critical condition and must be very sensitive to the effects of changes in the atmospheric pressure, the amount of precipitation of rain and snow, the variation in the weight of the sea water in the tidal movements, etc. These external agencies, which constitute the secondary earthquake causes, have evidently an important bearing on seismic phenomena when an earthquake is about to take place. It is, for instance, quite conceivable that the earthquake frequency in Tokyo is related to the precipitation of rain and snow along the northwestern coast of the main island (Nippon), where a large amount of the moisture is deposited during the winter months. This is, in fact, found to be the case, the seismic frequency and the amount of precipitation there varying from year to year in most remarkably close parallelism.

The idea that earthquakes occur in any special kind of weather

Large and small earthquakes show often opposite time distributions. This is what is to be expected from the nature of an earthquake, which is virtually equivalent to the removal of a weak point in the earth's crust, the more frequent occurrence of small shocks in an earthquake country tending to prevent any abnormal accumulation of the underground stress. An unusually low seismic frequency may, on the other hand, facilitate the occurrence of a severe seismic disturbance. In the Kyoto district in Japan small shocks are fewer in summer than in winter, while the violent destructive earthquakes have occurred only in the months of June to September.

In many countries earthquakes are popularly supposed to occur on moist, warm days. On the other hand, Carlyle says in his "French Revolution": "Hope ushers in a revolution, as earthquakes are preceded by bright weather." There certainly have been many earthquakes in bright weather, the great destructive shocks in Japan taking place, like the San Francisco disaster of 1906, almost without exception on very clear and calm days, when the whole country was covered by high barometric pressure.

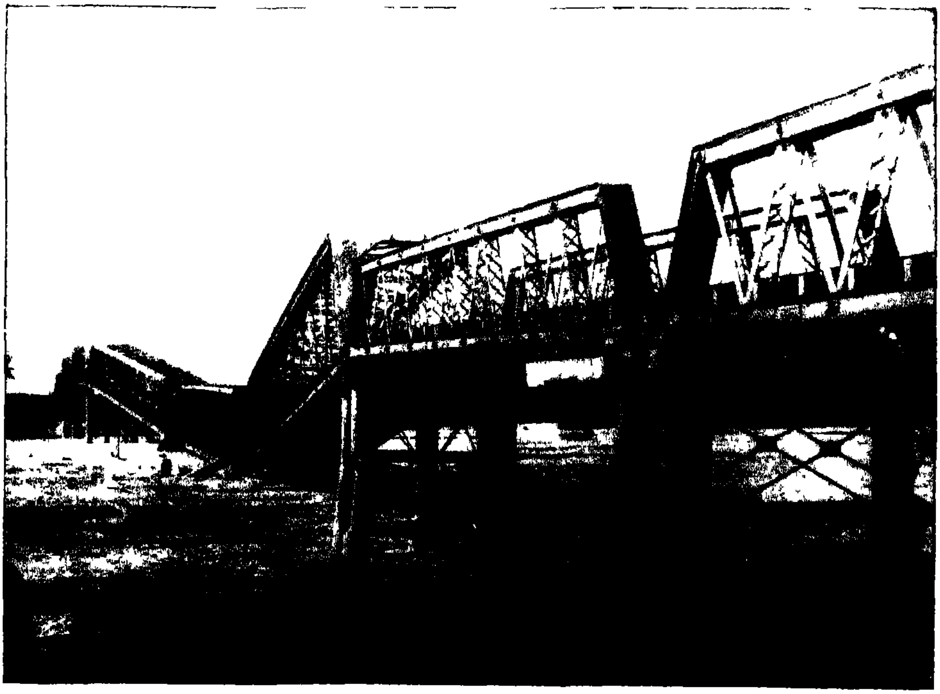
Although earthquakes are terrible and apparently mysterious phenomena, they are in some respects, governed by quite simple laws. Thus, a great earthquake is invariably followed by minor ones, whose number may run to hundreds or even thousands, and which may continue for several months or years. These secondary earthquakes, or "after-shocks," are quite natural, and necessary for the settling down into stable equilibrium of the disturbed tract at the origin of disturbance, and their mean time variation can be represented by means of a simple mathematical formula. For the great Central Japan (Mino-Owari) earthquake of 1891, Professor Omori calculated an empirical equation based merely on the frequency of the after-shocks instrumentally recorded in Gifu during the first five days following the catastrophe, and thus reached the conclusion that these small shocks would continue in that city for at least ten years with a total number of 4000. These predictions were completely verified by subsequent occurrences.

How "fore-shocks" often give warning of a coming earthquake

It often happens that precursory, or "fore-shocks," of different intensities are felt in the central district of a great earthquake. As the latter is generally due to the formation or enlargement of a fault or crack of considerable length in the earth's crust, it is quite natural that some of the weakest secondary points in the strained region should first give way and produce the minor shocks, before the dislocation or fracture along the whole extension of the focus produces the great final disturbance. To mention an instance, the destructive earthquake of Kagi (Formosa) in 1906 was preceded about five minutes by two severe shocks accompanied by loud noise. As these disturbances were quite unlike the ordinary earthquakes felt there, the people took alarm and many ran out of doors. Thus, it happened that a comparatively small proportion of the inhabitants remained within doors at the time of the final great shock, a circumstance which must have considerably reduced the number of casualties.

FREAKISH RESULTS OF EARTH TREMORS

A WOODEN HOUSE CROSSED BY THE LINE OF DISLOCATION

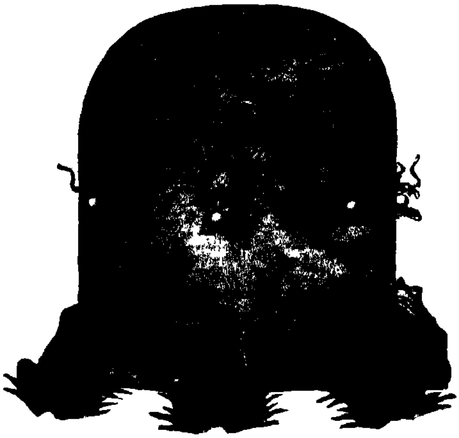


NAGARA RAILWAY BRIDGE DAMAGED BY CENTRAL JAPAN EARTHQUAKE OF 1891

The phenomena of fore-shocks, therefore, which are sometimes numerous and may occur several days before the principal disturbance, as was the case with the Japan earthquakes of 1854 and 1896, furnish a very interesting subject of study, giving practical importance to the tromometrical observation in earthquake countries.

Sea waves or "tsunami" often follow a great submarine earthquake

When an earthquake of inland origin is large and violent, the waters of ponds, rivers or lakes are more or less disturbed. So, similarly, a great submarine earthquake is often followed by tidal waves or "tsunami," sometimes sixty feet or more in height; the time interval between the occurrence of the earthquake shock and the arrival of the destructive sea waves varies from a few minutes to several hours, and depends on the distance of the origin from the shore. Tidal waves, which are not noticeable on the high sea, are developed most markedly in bays with shallow waters and open mouth, but are quite insignificant along deep-water straight coasts. Many of the great earthquakes originating off the Pacific coast of Alaska and Central and South America have been accompanied by great tidal waves. But, fortunately, this phenomenon, which sometimes causes more damage than the earthquake disturbance itself, is not very destructive along the coasts of the United States.



CHOKO'S SEISMOMETER, 132 A.D.

The great earthquake of April 18, 1906, produced distinct but very small disturbances in the waters of the bay, which were clearly recorded on the tide gauge at the Presidio (San Francisco), the amount of the rise and fall of the sea being only about six inches, repeated in about forty minutes. Now the wave period or periods at a place on a given coast remain constant in all tidal waves, irrespective of the origin or cause, a destructive tidal wave consisting simply in the increase of the amount of the water motion existing more or less at all times, in consequence of a severe submarine earthquake or eruption, a storm or some other agency. A seismic tidal wave is caused by the movements communicated from the sea bottom to the superincumbent water mass, a large water disturbance taking place when the earthquake's focus is at the sea bottom itself or at a very small depth below it, accompanied by some changes in the contour of the sea bottom.

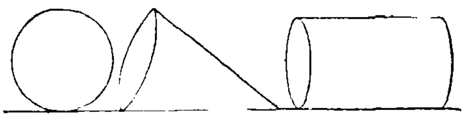
The "tsunamis," which followed the great Japan earthquake of December 23, 1854, spread across the Pacific and reached San Francisco, 4527 nautical miles distant from the source of disturbance, in the time interval of $12^{h}\ 40^{m}$, leaving traces on the tide gauge diagrams at the Presidio and also at San Diego and Astoria. On the occasion of this shock the Russian frigate *Diana*, at anchor in the harbor of Shimoda, was destroyed by the "tsunami." It was from the crew of this ill-fated vessel that the Japanese first learned the art of modern shipbuilding.

Seismological instruments: Choko's early seismometer and its successors

On the occasion of the San Francisco earthquake of April, 1906, the steamer *Argo* felt the shock at sea near Cape Mendocino, the sensation being like that caused by running aground. There were other vessels which felt the earthquake in a similar manner. Effects like these, which may be called "sea-shocks," are due to the direct transmission through the water of vibratory earthquake movements, and are not due to the phenomena of the tidal waves, which are developed only along coasts where there is some indentation.

The first seismological instrument ever invented was that constructed by a Chinese named Choko, dating back to 132 A.D. As will be seen from the illustration, it consisted of a closed bronze vessel about eight feet in diameter, with a hidden mechanism within, which, at the time of an earthquake, caused the balls to be dropped down from some of the dragon heads into the open upturned mouths of the frogs below; the latter, thus thrown into oscillation, indicated the direction of the earth's movements. It is recorded that once some of the dragons dropped the balls, but there being no sensible shock, the people wondered why, and it was not until several days later that it was learned that there had been an earthquake in one of the western provinces. Thus Choko's instrument was really a sort of seismoscope, giving indications of the occurrence even of unfelt movements.

An ordinary pendulum, or heavy weight suspended by a string or rod, is a familiar example of the class of bodies whose equilibrium is stable, going back after displacement to the same position of rest.

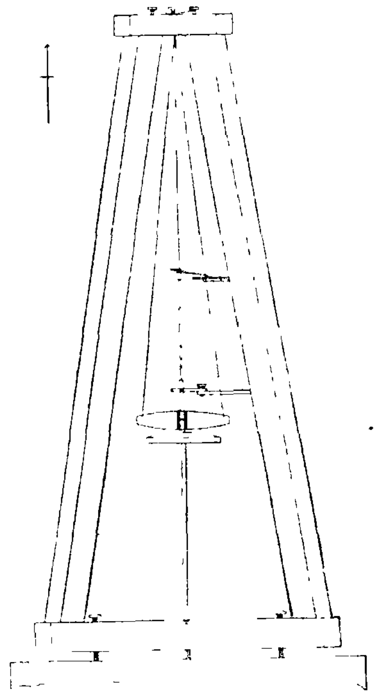


IN NEUTRAL EQUILIBRIUM

On the other hand, an inverted pendulum, composed of a heavy weight supported by a vertical rod, is unstable — even a slight displacement altogether changing the condition of equilibrium. Again, a sphere, a cone or a cylinder, resting on a horizontal plane, is neither stable nor unstable, but is in a neutral equilibrium, any displacement from the condition of rest producing no force which deranges the equilibrium. It is to be observed that when the earthquake is sufficiently severe, a body in stable equilibrium magnifies the motion by the addition of its own vibrations, while one in unstable equilibrium will be entirely overthrown. The characteristic of a body in neutral equilibrium is that it minimizes the earthquake effect, there being neither amplification of motion nor tendency to upset.

Principle of construction of the modern seismograph

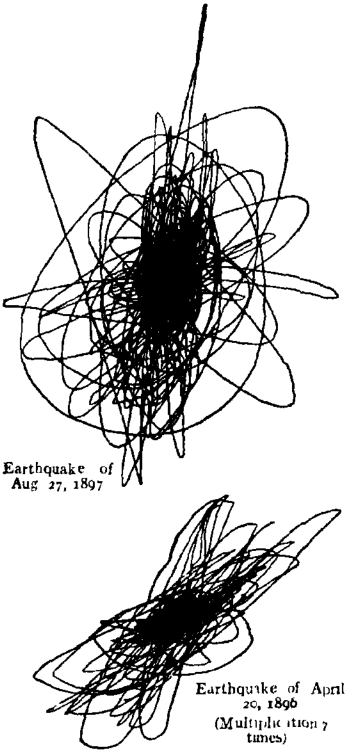
The principle of construction of modern seismographs consists in providing a steady point, which remains unaffected by the earthquake motion and with reference to which as the fulcrum the motion of the ground can be recorded by means of a pointer. The registration is taken in two components, the vertical and the horizontal.



DUPLEX PENDULUM SEISMOGRAPH
(scale $\frac{1}{8}$)

The principle of construction of the duplex pendulum seismograph, originally designed by Professors Gray, Ewing and Milne, is very similar to that of a Japanese pagoda or bell-tower. The instrument is made up of an ordinary pendulum coupled to an inverted one in such a way that the combined system forms a mass in neutral equilibrium and provides a point serving as the fulcrum of the writing pointer. The record, giving the actual resultant horizontal motion of an earth-particle during the shaking, is taken either on a stationary smoked-glass plate or on a continuously moving smoked paper.

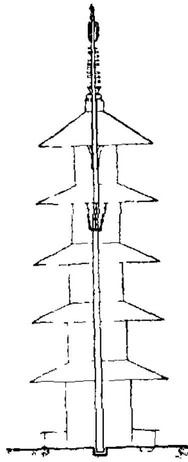
A Japanese pagoda or five-storied temple tower, which in spite of its slender and apparently unstable form can never be overthrown by an earthquake, is composed of a timber framework and an inner central wooden pillar supporting the heavy vertical metal rod projecting above the top roof. In the pagodas constructed before the 17th century the central pillar rests on the ground, but in those of more recent date it is suspended on chains, so that the lower end is not in contact with the ground



TOKYO RECORDS, DUPLEX PENDULUM SEISMOGRAPH

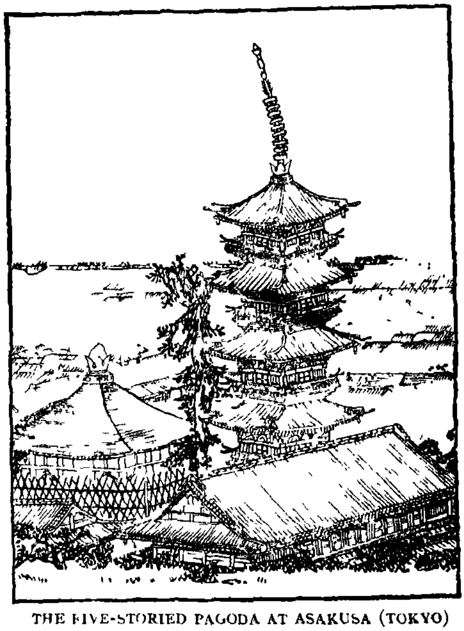
and forms actually a large pendulum, while the rest of the structure may be regarded as an inverted pendulum. Thus the building is a combination of stable and unstable parts and is in a condition approaching neutral equilibrium, thereby tending to minimize the earthquake effect. In the violent Yedo (Tokyo) earthquake of 1854, the pagoda at the Asakusa park had the top metal post considerably bent, the tower itself receiving no injury.

A Japanese bell-tower is composed of a heavy tiled roof supported by four stout wooden posts 12 to 20 feet high, and forms a sort of inverted pendulum, while the bell



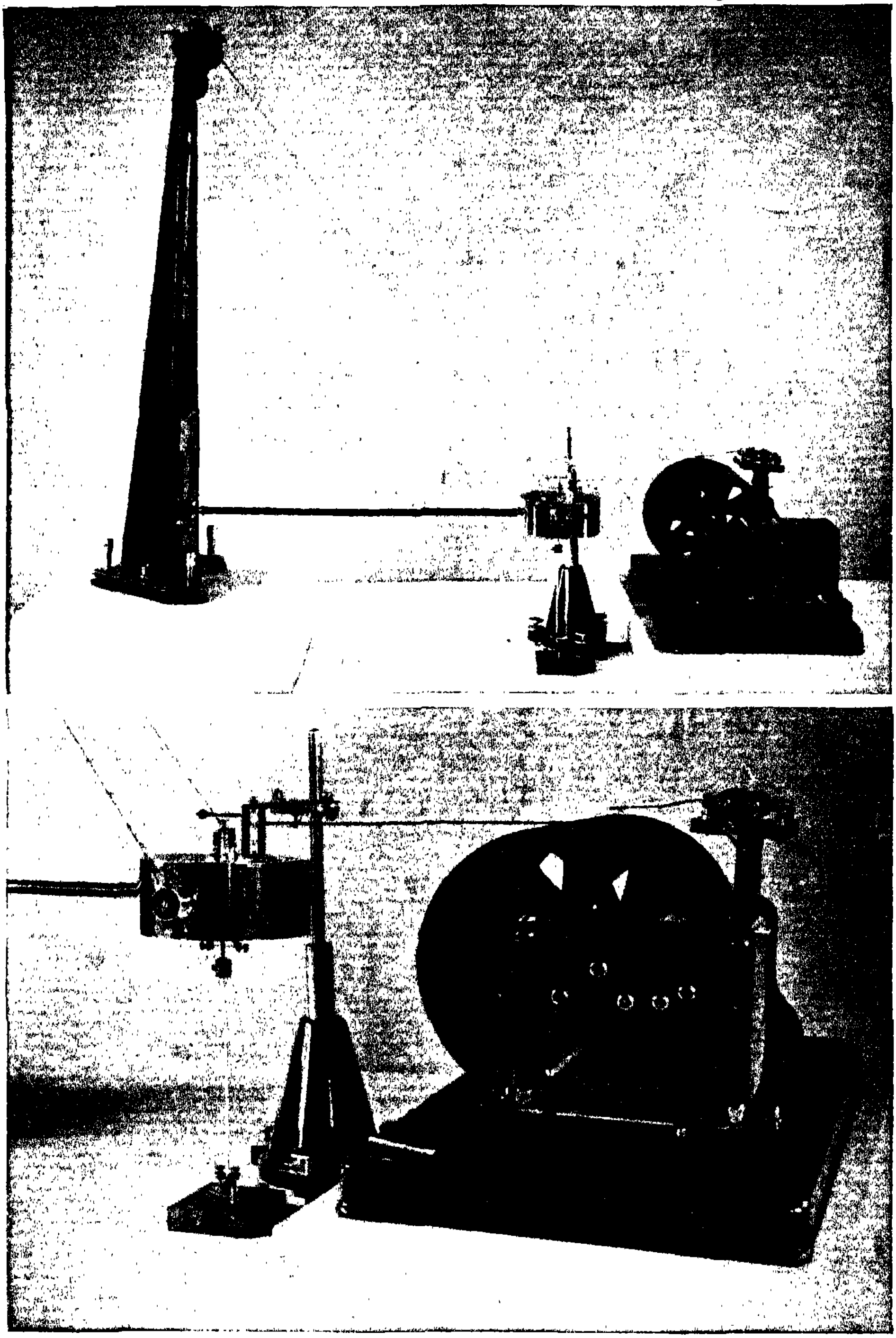
PRINCIPLE OF CONSTRUCTION OF A JAPANESE PAGODA

itself, being suspended freely, forms an ordinary pendulum. Thus the structure, the principle of construction of which is similar to that of the pagoda, can resist any earthquake and is never overthrown unless the supporting columns be broken.



THE FIVE-STORIED PAGODA AT ASAKUSA (TOKYO)

A MODERN RECORDER OF EARTHQUAKES



OMORI'S DUPLEX HORIZONTAL PENDULUM SEISMOGRAPH

The upper view shows the entire instrument (scale $\frac{1}{18}$), the lower gives an enlarged picture of the right-hand half, the automatic registration end.

The great bell, about 74,000 pounds in weight, of the famous Todai-ji temple, in Nara, was thrown down, from the failure of the suspension hook, three times by earthquake shocks (in 1070, 1096 and 1177), the bell-house itself, however, remaining undamaged.

For purposes of record, the horizontal motion is decomposed into two rectangular components, such as E-W and N-S. One class of horizontal motion seismographs, widely in use, consists of a horizontal pendulum, in which the steady point is furnished by the center of a heavy cylinder pivoted along its axis to a frame, which is itself pivoted about a nearly vertical axis to a stand fixed to the base plate.

When, then, the shock comes in the plane of the axes, the pendulum simply suffers a displacement as a whole, but if the ground moves horizontally — *i.e.* perpendicularly to this plane — the system turns about the steady point (axis) and a pointer attached to it traces the motion of the mass relatively to the earth, multiplied any required number of times, on the smoked paper wrapped round a rotating cylinder. Two such pendulums placed at right angles to each other will trace out the earth motion completely. Our illustrations show the chief parts of Professor Omori's horizontal duplex pendulum instrument adapted for the automatic registration of ordinary earthquakes and tremors.

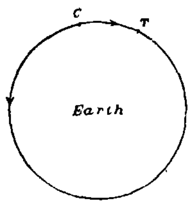


Diagram illustrating the propagation of earthquake waves along two sides of the earth.

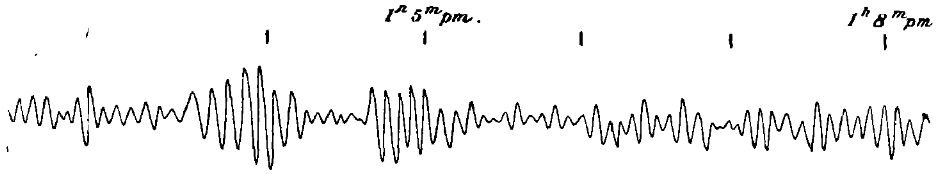
In vertical motion seismographs spiral or flat springs are made to support a heavy weight, a proper device being introduced for rendering the equilibrium of the system neutral.

Earthquake motion, its nature and degree of intensity

The earthquake motion begins with vibrations of small amplitude and comparatively short period, known as the "preliminary tremors"; next come those of large amplitude, composing the main and most active part of the disturbance; and finally the motion ends with feeble vibrations.

The motion of the earth's crust, which consists in general of several sets of waves of different amplitude and period, may be divided into two classes, namely, the sensible and the insensible. These are sometimes distinguished as "macro-seismic" and "micro-seismic," although these terms have also been employed in a quite different sense by some seismologists. The amplitude of some vibrations in the insensible motion is as large as, or even larger than, that of vibrations in small but sensible local earthquakes; they are insensible only because their period is very long, and consequently their acceleration small.

Even when we do not actually feel an earthquake the ground is generally making some insensible movements, which may be divided into two kinds according as they are or are not of seismic origin. The vibrations not due to earthquakes have been called "pulsatory oscillations," while the others are those due to very distant earthquakes or to near but slight ones. The pulsatory oscillations are most markedly shown in places like Tokyo or Osaka, situated on an extensive plain or new formation, and generally accompany the effect of a cyclone sensible at a distance of over 600 miles. In Tokyo, earthquakes occur rather rarely, while pulsatory oscillations are actively going on; there often being, on the other hand, local shocks when these oscillations come to a state of minimum activity.



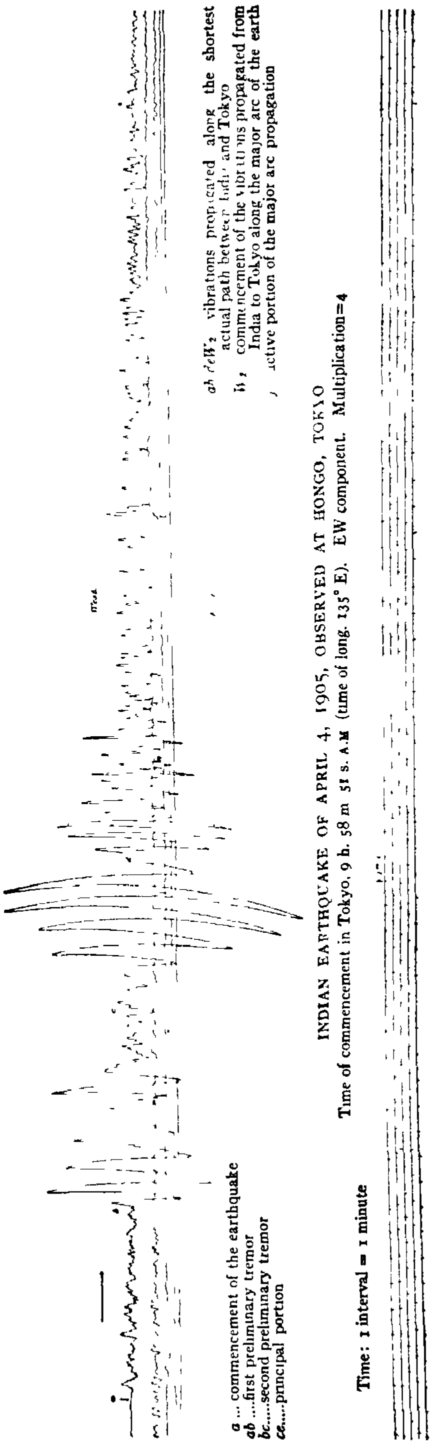
PULSATORY OSCILLATIONS IN TOKYO OBSERVED ON FEB. 1, 1908. MAGNIFICATION = 120. EW COMPONENT

The vibrations due to an earthquake, even when very large, cease to be sensible at great distances from the source of disturbance. The seismic motion spreads, however, all over the world and can be recorded by sensitive seismographs. In fact, the waves of a great earthquake, whose total duration is often three to five hours, reach a given place in the following three different ways: first, the motion propagated along the shortest surface path; second, the wave propagated in the opposite direction, arriving at the station after passing the antipode of the origin (C); and third, the repetition of the first wave coming back to the station after passing its antipode. The vibrations composing the principal or most active portion of the earthquake motion have a velocity of 3.3 kilometers, or 2 miles, per second and take $3^{h.}\ 20^{m}\ 46^{s.}$ in going completely round the earth. The figure at the right, which is the EW component diagram of the Kangra (British India) earthquake of April 4, 1905, recorded in Tokyo, indicates the major-arc propagation very clearly.

The position of an earthquake origin can, among other things, be most accurately determined from the seismograph records. Thus, the duration of the preliminary tremor of the earthquake observed at a given place is proportional to the radial distance, while the vibrations in the earlier part of the same stage of motion indicate the direction in which the origin of the seismic disturbance is situated.

The ordinary sensible earthquake motion is quite small. When it reaches a few inches, the effect becomes destructive. The maximum horizontal and vertical ranges of motion of the severe Tokyo earthquake of 1894 were at the University grounds (Hongo) respectively 3.0 and 0.4 inches. The maximum horizontal motion in Nagoya on the occasion of the great Mino-Owari earthquake of 1891 was about 9 inches.

In cases of near-at-hand earthquakes, a rumbling sound like distant thunder or a rushing sound like a blast of wind is heard just before, or simultaneously with, the arrival of the tremblings of the ground. These sounds are of frequent occurrence in rocky districts, but rare in the plains.



INDIAN EARTHQUAKE OF APRIL 4, 1905, OBSERVED AT HONGO, TOKYO
Time of commencement in Tokyo, 9 h. 58 m 51 s. A.M (time of long. 135° E). EW component. Multiplication=4

For the discussion of the destructive seismic effects we must have an absolute measure of the intensity of motion; this may be represented by the maximum acceleration of the earth particle, which is proportional directly to the amplitude, but inversely to the square of the period. For ordinary non-destructive earthquakes this maximum acceleration is small and under 200 or 300 mm. per second; the shock being a destructive one when it reaches 2000 mm. per second. The acceleration just sufficiently strong to be perceptible to us without instrumental aid is found to be about 17 mm. per second. The duration of the main part in destructive earthquakes, which varies generally between 4 and 10 seconds may in cases of extraordinarily violent shocks amount to 26 to 28 seconds.

The earthquake motion is generally intensified in a loose, soft soil; and, on the occasion of a great destructive earthquake, the shock is very much stronger in moist soil than in hard ground. The seismic effect will similarly be felt very severely in a valley district, where loose soil is superposed on a hard formation. At the edge of a steep bank or slope, the motion is intensified on account of want of a side support. To this phenomenon of marginal vibrations is due the formation by earthquakes of cracks along the river banks and the occurrence of landslips from mountain sides.

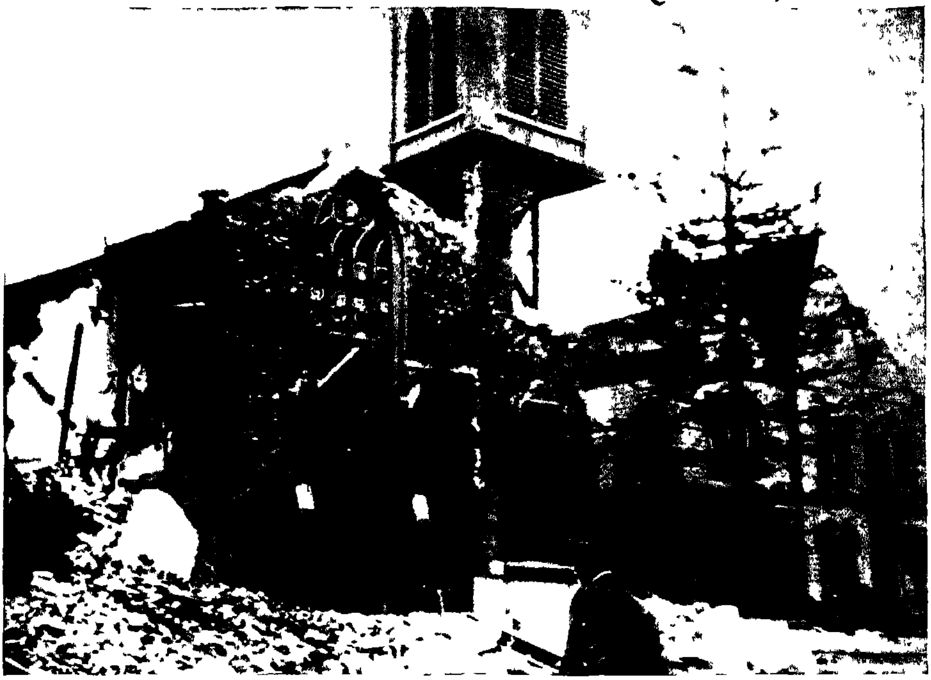
In destructive earthquakes the ground surface may, under certain circumstances, be thrown into gravity waves of short wavelength, in just the same way as strong earthquakes cause waves in lakes and seas. The earthquake movements must then be accompanied by a considerable amount of tilting of the ground. This probably accounts for the statement often met with in narratives of earthquakes that the ground was thrown into wavy forms. Further, in the epicentral districts of great earthquakes, several cases have been observed in which the plane surface of the ground was transformed into permanent curved forms, these disturbances usually taking place on paddy fields or other soft marshy ground.

In the Messina-Reggio earthquake of December 28, 1908, the seismic disturbance reached Tokyo at $1^{h}\ 32^{m}\cdot 08^{s}\cdot$ P.M. (time of longitude 135° E.). Calculating from the duration of the first preliminary tremor, the time interval taken by the vibrations of the latter phase of motion in traveling through the distance is found to be $11^{m}\cdot 51^{s}\cdot$. Consequently, the time of occurrence in the epicentral area ought to have been about $5^{h}\cdot 20^{m}\ 17^{s}$ (Central European time). As a matter of fact, a clock in Via Porta Imperiale in the city of Messina and also that of the railroad station of Villa S. Giovanni, stopped by the earthquake shock and left untouched during several subsequent months, were found to indicate the time as about $5^{h}\ 20^{m}\cdot$.

The San Francisco earthquake occurred at $5^{h}\cdot 12^{m}\cdot$ A.M. (Western time), April 18, 1906. The area within which more or less damage was done was very long, extending over a distance of 550 miles along the Pacific coast, from the vicinity of Salinas on the south to that of Eureka on the north. The width, or the extent from the coast, of the strong motion area was some 50 miles. The total number of killed in the whole earthquake area was probably not more than 1000, the loss of life in Santa Rosa, Stanford University and other severely shaken places being slight. In San Francisco serious damage was confined to the filled-in grounds, the maximum motion being probably some 4 inches.

One of the peculiar features in the topography of the state of California is a straight depression along the valley of Gualala River and Tomales and Bolinas bays, continued further southeastward for some distance This depression shows signs of dislocations caused at no very remote epoch by some great earthquakes, and the earthquake of April 18th again produced along the same old weak zone a continuous series of remarkable surface manifestations of crack or horizontal slipping, constituting what in geology is called a "fault." This fault began on the north at the mouth of Alder Creek, near Pt. Arena, and passed into the ocean in the vicinity of Fort Ross; it again appeared at the Bodega Head and at the

THE SANTA BARBARA EARTHQUAKE, 1925



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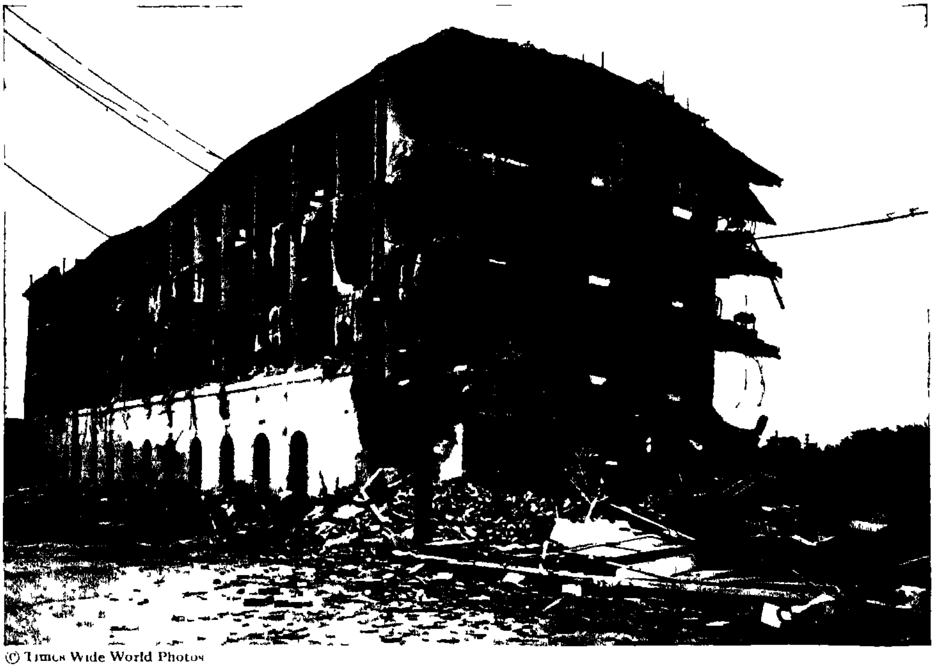
A church in the city of Santa Barbara, California. The belfry is left standing on one wall, while practically all of the other walls were demolished.



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The walls of this hotel were sliced off, but in many of the rooms the furniture did not move an inch out of place.

eastern side of the mouth of Tomales Bay, crossed to Inverness on the west shore of the same bay, and then passed through the vicinity of Pt. Reyes Station, continued to about 4 miles to the west of Stanford University; marked disturbances of the ground being also distinctly shown to the southeast, in the vicinity of Wright and Chittenden. The length of the visible fault is thus over 150 miles, it being probable that the northwestern part of the fault was continued beyond Pt. Arena under the ocean some 120 miles more and extended to the vicinity of Cape Fortuna. That the fault was not a mere surface phenomenon is shown by the appearance of the same disturbance across the tunnel near Wright Station, at a depth of some 700 feet below the mountain surface. The shearing movement of the ground produced many remarkable results: roads, fences, piers, etc., crossed by the line of disturbance being cut apart and displaced to the maximum amount of 21 feet.

Seismic experiments and their application to construction methods

For the practical application of seismology to construction methods in earthquake countries, it is necessary, besides the observation of the damage due to actual earthquakes, to investigate experimentally the effects of artificially produced movements on various models, the ultimate object being the calculation of the seismic stability of given structures and the finding of the forms best suited to withstand earthquakes. For this purpose, in Japan, strong artificial earthquake motion was produced by means of a shaking table, designed by Professors Mano and Inokuchi, which consists of a stout wooden floor properly mounted on strong supports, and which can be made to move with independent horizontal and vertical, simple, harmonic oscillations 1 to 6 inches in range. A great number of experiments made on the fracturing, overturning, rotation and sliding of brick, stone, iron and wooden columns and plates enabled them to establish certain formulæ approximately applicable to bridge piers, chimneys, walls, etc.

The period of natural vibration or rocking of a body is a very important factor in the discussion of the overturning phenomena. If this period be much greater than that of the earthquake motion, the body may be regarded as rotating about its center of percussion with respect to the base. In other cases, however, the body is to be supposed as being acted on by a force equivalent to the product of its own mass and the maximum acceleration of the earthquake motion applied at its center of gravity.

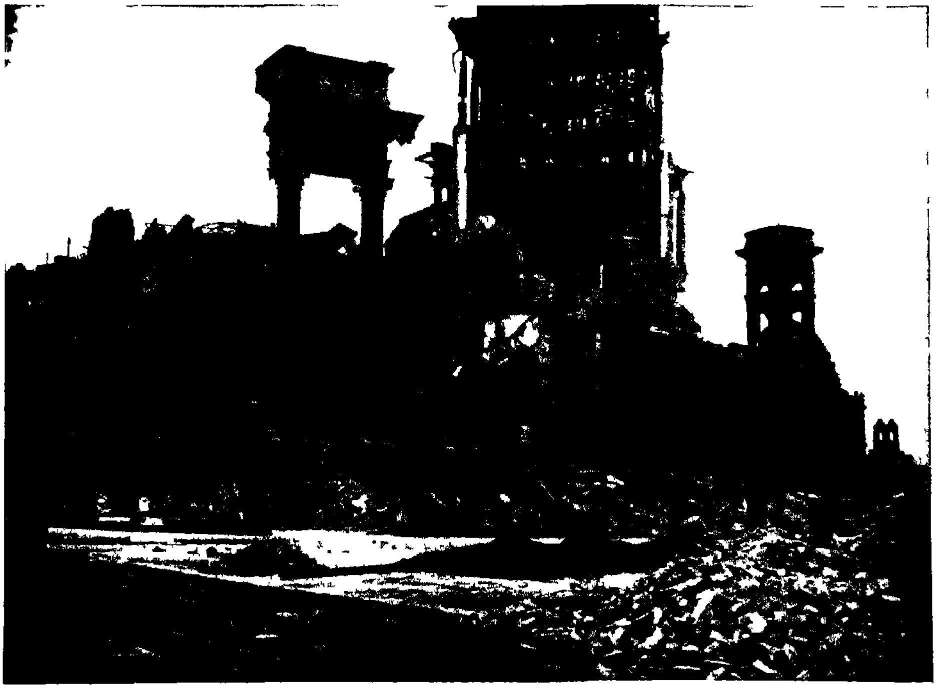
How earth cracks are produced

Earth cracks are produced when the range of motion exceeds the elastic limit of the ground, and ought consequently not to be completely closed again. They are often several feet wide at the mouth and evidently of a considerable depth, and emit water mixed with pale bluish sand. Yet, being zigzag in formation, the direct vertical depth amounts only to five or six feet, so that even if a man should fall into one of them, he can easily climb out. There is no danger of houses and people being swallowed and crushed in the cracks, as is popularly believed. In the Sakata (Japan) earthquake of 1894, a wooden school building remained uninjured in spite of the formation of cracks four feet in width right under it, and in San Francisco a wooden house on ground crossed by the dislocation line was much shattered but remained standing.

In the Japanese style of architecture, in which the timber framework simply rests upon the foundations, the destructive effect is partially prevented from being communicated to the building when the intensity of the earthquake motion exceeds the frictional resistance between wood and stone. The result is that so long as the posts are not broken the houses remain standing, even though they may slide bodily to the extent of one to three feet, as was the case with the cottages at the most central part of the epifocal zone of the tremendous Central Japan earthquake in 1891. Wooden structures fall flat only when the horizontal motion is strong enough to fracture the pillars.

MUTE EVIDENCE OF TREMENDOUS FORCE

A STREET IN SAN FRANCISCO AFTER THE EARTHQUAKE OF 1906



CITY HALL, SAN FRANCISCO, DAMAGED BY THE EARTHQUAKE

It took 12 years to build and 12 seconds to destroy this splendid building

A well built wooden house can resist any violent earthquake, even though wide cracks be formed on the neighboring ground or under it. One of two stories has a tendency to lose its upper story as a whole.

Brick factory chimneys are easily broken off by earthquakes, generally at about two-thirds of their height, due to the comparative slowness of their natural oscillation period. It often happens that the broken portion remains, entirely or partially, in position, suffering only a displacement or a rotation. On the other hand, iron chimneys have a quick oscillation period and are, in consequence, weakest at the base, just as is the case with walls, bridge piers, gate-posts, tank-towers, etc. Reinforced concrete chimneys less than about 150 feet in height have a natural oscillation period not much varying from one second, and are weakest at the base; very tall ones, such as the great 550-foot chimney of the Kuhara Mining Company at Saganoseki (Kyushu, Japan), have the long period of about two and a half seconds and ought, therefore, to be weakest at about two-thirds of their height. Ordinary house chimneys, which constitute a source of danger in cases of strong earthquakes, are very easily damaged by the shock at their junction with the roof, the pieces often falling through the latter.

Large structures, even when very tall, would never be overturned as a whole by an earthquake except in cases where their foundations give way. Consequently frame buildings are safe against earthquakes so long as their uprights remain unbroken. Properly built iron and brick structures are, on the whole, earthquake-proof, although a strong seismic disturbance may cause cracks in the walls and slight damage to the iron beams. The skyscrapers of New York are subject to no great risk of earthquake damage, as they are simple in form and as the ground in that city is hard and anti-seismic. Reinforced concrete furnishes the best material of construction for earthquake countries, rendering it possible to build houses, chimneys, etc., in which reduction of weight is combined with considerable seismic stability.

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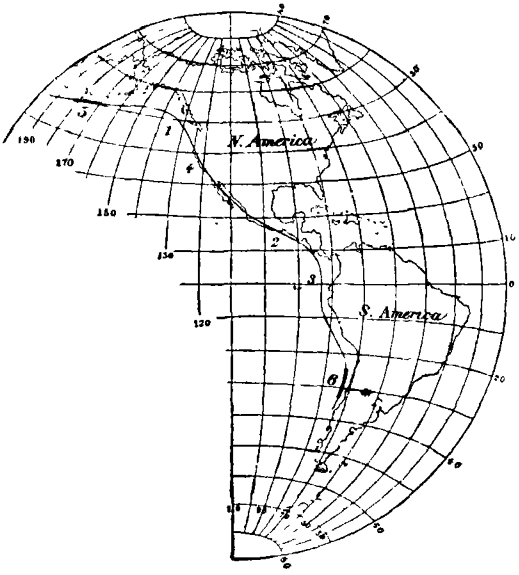
REMARKABLE FREAK OF JAPANESE EARTHQUAKE, 1923

The shock of the Yokohama earthquake tumbled this electric car headlong into the canal, but the car was practically uninjured.

Earthquake zones and the occurrence of earthquakes along lines of weakness

Seismologically the earth may be divided into two regions, the Arctic and the Pacific. In the former seismic activity is slight, while in the latter it is very great. In fact, the whole Pacific coast of South and North America, the Aleutian Islands, Japan, Formosa, the Philippines, the Dutch East Indies, etc., continued to the outer base of the Himalayas, Turkestan, Caucasus, Asia Minor and the northern shores of the Mediterranean, may be regarded as forming the greatest seismic band of the world.

Within the seven years preceding the great San Francisco earthquake, there were along the Pacific coast of the American continents seven terrible earthquakes, of which three took place off the southeastern coast of Alaska, three severely shook Mexico and Guatemala, while the seventh (February 1, 1906) caused damage in Panama, Colombia, and Ecuador. As these seven were not unconnected local phenomena, but must have been the result of a great stress accumulation along the coast of the two Americas, relieved at its northern and middle parts, an event most naturally to be expected would have been the extension of the seismic disturbance to the west coast of the United States, which so far had been free from the visitation of disastrous earthquakes. This was verified in the San Francisco earthquake of April 18, 1906.



MAP SHOWING APPROXIMATE LOCATIONS OF DIFFERENT GREAT EARTHQUAKES ALONG THE WEST COAST OF AMERICA

(1) Alaska earthquakes of Sept. 4 and 11, 1899, and of Oct. 9, 1900
(2) Mexico and Central America earthquakes of Jan. 20, 1900, and of April 19 and Sept. 23, 1902.
(3) Panama, Colombia, and Ecuador earthquake of Jan. 31, 1906
(4) San Francisco earthquake of April 18, 1906
(5) Aleutian Islands earthquake of Aug. 16, 1906
(6) Valparaiso earthquake of Aug. 16, 1906

At that time Professor Omori expressed the view that the next shock would be south of the equator, in Chile or Peru, as it was very likely that the seismic activity would extend to either end along the great zone in question. This anticipation was confirmed by the very severe shock of Valparaiso on August 17, 1906, and it is further remarkable that, on the same day, there was almost simultaneously another considerable shock off the Aleutian Islands. The centers of these two earthquakes were separated by a distance a little over two-thirds of the earth's semi-circumference. In the other hemisphere there was more recently a manifestation of equally great seismic activity along the Mediterranean and Himalayan branch seismic zone, twelve great earthquakes having taken place in Italy, Macedonia, Asia Minor, Caucasus, Turkestan, northern India and Formosa. That violent destructive earthquakes in a given region do not occur at random, but along definite lines of weakness in the earth's crust, namely, seismic zones, was also demonstrated by the Messina-Reggio earthquake of December 28, 1908, and the thirteen other great destructive shocks which occurred since 1638 in central and southern Italy. The centers of origin of these fourteen earthquakes together form a continuous seismic zone, which extends from central Italy, through Calabria, down to the vicinity of Catania. Further, the areas of violent motion of these different earthquakes were almost perfectly exclusive of each other, illus-

trating the principle that great disturbances are not repeated at one and the same center, but happen successively at different points along a seismic zone. In other words, the places seismically most dangerous in central and southern Italy are exactly those points along the line of disturbance in question which have not yet been visited by a very violent shock. The two cities of Messina and Reggio-Calabria, which formerly had not been shaken by a great telluric convulsion originating from a center close by, evidently had their turn in 1908 and may be supposed to be free from future danger. The principle of the

MAP SHOWING THE MUTUAL RELATION OF THE GREAT EARTHQUAKES IN CENTRAL AND SOUTHERN ITALY

The area 14 is the violent motion district of the Messina-Reggio earthquake of 1908; the areas 1 to 13 are the similar districts of the previous thirteen great destructive earthquakes. Number 15 (X) indicates the site of the origin of the Avezzano earthquake of 1915.

"earthquake zone" found more recently a verification in the great Avezzano earthquake of January 15, 1915, which originated just where it ought to have occurred, namely, in central Italy and at a particular portion of the earthquake zone running through the middle of the peninsula which had remained previously unshaken.

Earthquakes of volcanic origin, which are quite numerous and often fairly severe, can never attain the intensity of a great destructive shock, that is to say, will not be able to destroy the ordinary wooden-framed house. Brick chimneys, stone walls, badly constructed masonry buildings, etc., may be easily broken even by moderate shocks, and care must be taken to make them strong.

Although the problem of the prediction of destructive earthquakes is still very far from its solution, yet a considerable light has already been thrown on the causes, the geographical relation and the time distribution of earthquakes, such that we can determine in many cases the probable intensity and direction of motion in a future shock at a given place, or the next locality along a given earthquake zone likely to be shaken by a great earthquake, and in some special cases the probable epoch of earthquake occurrence. On the other hand, it is always necessary to build houses and factories so as to resist earthquake shocks.

The fact that a very slight amount of precaution taken against earthquakes is sufficient to save considerable loss of life and property is well illustrated by the comparison of the seismic damage to Italian and Japanese cities. Thus, in the Italian earthquake of December 28, 1908, the total number of victims was over 100,000, of which about 75,000 were in Messina and the suburbs, and the remaining 25,000 in Reggio and other places in Calabria. The intensity of earthquake motion in Messina was a little less than that in the city of Nagoya on the occasion of the Mino-Owari earthquake of 1891. The population of Nagoya in 1891 was 165,339, which was nearly equal to that of Messina and the vicinity, and only 190 were killed in the earthquake. Even supposing the intensity of seismic motion in Messina to have been equal to that in Nagoya, the number of persons killed in the former city was about 430 times greater than that in the latter; that is to say, about 998 of every 1000 of the number killed in Messina must be regarded, when compared to the Japanese city, as having fallen victims to seismologically bad construction of the houses.

WHY THE BODY MUST DIE

The Meaning of Physical Death in the Scheme of Nature, and the Place of the Individual in the Scale of Ascending Life

FROM BIRTH TO DEATH AND DEATH TO BIRTH

LIFE can exist only under certain conditions, and if these be lacking it ceases. A great part of all death is due to some form of interference with these conditions — to battle and murder and accident and starvation and poisoning. Some of these forms of death are of the utmost importance in the history and progress of life, for the death by violence of one species may mean the life, the well-fed life, of another; and death by starvation raises the whole question of the struggle for food, which is half the drama of the world.

But here we are faced with a different question, which is concerned with the fact of what we may call natural death. This is not to say that the other forms of death are unnatural, but we require a special term to indicate the form of death which is due to no accident or murder or lack of the needs of life, but depends upon an internal and inevitable necessity in the nature of the living thing. Unless we once for all grasp this fundamental distinction between "natural" or "physiological" death and all other forms of death, we shall never be able to unravel and understand our problem — the problem of death — as one of the universal and appointed facts of life.

We require definitely to satisfy ourselves that there is such a thing as natural death. In our own lives we are beginning to learn that death may often be averted, and that the greater part of human death is, at the least, premature. We may almost be excused for rushing to the conclusion that, if only we knew still more about diet, and "auto-intoxication," and all the rest of the vocabulary of the modern food-reformer and "health-culturist," we might avert death indefinitely. And among the humbler forms of life we see death so constantly due to accident, change of weather, starvation, and, above all, to the attacks of other life — as when the bird eats insects or the cat the bird — that there also we may suppose that, if special protection were afforded, any living thing might continue to live on indefinitely.

But it is not so. We may admit that wiser and better conditions — not necessarily *easier* conditions, but that is another and a tremendous story — would prolong the span of life for almost all individuals of all species, but not indefinitely. We observe that our domestic pets grow old from maturity as inevitably as they grow up from infancy. It is as definitely part of the preordained and unchangeable nature of the cat that it shall grow old *and die* as it is part of the nature of the kitten that it shall grow to be a cat. The necessity of natural death is thus in the kitten, and was in it from the first instant of its individual life. We are all necessarily walking to our own funerals, so far as physical life is concerned; and what is true of all forms of animal life is true also, though with some qualifications, of all forms of vegetable life. Death is one of the inherent attributes of life.

We are thus faced with a paradox, the greatest paradox in nature. Having surveyed the living world, we saw at least as far as this — that life will not give in, that it ever demands more and more expression, and that all its attributes exist for its service.

Death as universal a fact of living things as any we can observe

The leaf of the plant, the claws of the tiger, any attribute or characteristic, without any important exception, of whatever living creature we choose to study — all exist for the furtherance, enhancement, multiplication, aggrandizement of life. Yet at the very outset of our study, and without a moment's interval after we have realized this concentrated, unshakable, devoted striving of all the living world and all its attributes, we find ourselves faced with death, which is at least as universal a fact of living things as any that we can observe. If this be an exception to the rule, it must either, in some apparently incomprehensible fashion, be an exception that proves the rule, or else it must break the rule altogether. How can we regard "more life and fuller" as the aim of all life if we find that all living beings are constructed and intended to die?

The theory known as "the survival of the fittest"

As we shall learn later, the living world displays characteristics which give strong support to the theory known as "natural selection," or "the survival of the fittest." According to this theory, not merely are living things made in order to achieve as much life as possible, but all existing forms of life are the survivors of an age-long struggle in which victory always goes to those that are "fittest" — those that have the greatest numbers of features which, in their struggle against the exigencies and vicissitudes of their environment, enable them to survive. We therefore speak of the "survival-value" of a backbone, or a trunk, or an instinct, or a wing, or an intelligence, or a tearing tooth, or any other feature of any individual of any species. It is true that, since this theory was first stated, we have discovered that sometimes new forms of life appear which may not have any survival-value of their own — say, for instance, toy dogs, some of whose features are a handicap, and would be fatal in the ordinary way.

The survival-value of death which enables it to persist and make for more life

But though we must note this lest we find ourselves in contradiction when we come to consider the principles of Mendelism, many authorities maintain that the great and general characteristics of living beings have been formed under the influence of natural selection, which has always and necessarily favored the survival of whatever made for life, and has incessantly and ruthlessly pruned away whatever made for death. Yet this character, death, has survived in the struggle for existence; and the law of the "survival of the fittest" must either be nonsense, or else we must demonstrate what seems the utmost absurdity — the survival-value of death.

Evidently we cannot mean the survival-value of death to the oak or herring that dies. Its death cannot promote its life. But it is possible that its death may promote the life of the species to which it belongs, and thus death would mean, in the long run, the making of more and fuller life. The great student and thinker who first sought an answer to this tremendous question was August Weismann, the German biologist, to whom our knowledge of heredity is so much indebted. As a devoted follower of the theory of natural selection, Weismann saw that this theory must either be abandoned or it must be proved that death makes for life, and has thus been encouraged by natural selection, just like the other characters of living beings, locomotion, sensation, teeth, and what not, which obviously make for life.

Weismann's famous essay studied in the light of today's knowledge

Weismann's famous essay was written a long time ago; and here we may restate the case as it can be seen today, but not forgetting our debt to this great man.

Substantially, indeed, we can add nothing to what he showed many years ago; and certainly we must follow his method, which was to study the forms of life up from the humblest known, and thus to explain death by discovering its birth.

ONE GENERATION PASSETH AWAY AND ANOTHER COMETH, BUT THE EARTH ABIDETH FOREVER

THE HARBOR OF REFUGE — FROM THE PAINTING BY FREDERICK WALKER, A R A.

For Weismann showed that, if the first forms of life to appear on earth were like the simplest now known to us, death was not part of the living world at first. It has been evolved, as backbones and brains have been evolved; and the key to it lies in its origin, in the circumstances which led up to the birth of death.

The birth of death, and the living things that do not die

We have already seen, as Weismann was the first to point out, that the single-celled creatures, which divide into two and so continue, do not die. Death, as we understand it, does not occur at all. The individual amœba, or bacillus, disappears, but no part of it has died. These creatures are, therefore, in a sense immortal. What we mean by natural death does not exist at this level in the scheme of life.

In both plant and animal worlds of today we find these single-celled organisms and, although science cannot prove that such is the case, most biologists believe that the many-celled forms of plants and animals now in existence have originated in the distant past from unicellular ancestors similar to these. In the case of the unicellular organisms all the functions of life must of necessity be fulfilled by the single cell and, consequently, every cell performs the same functions. But with the multicellular forms it is entirely different, some of the cells discharging one function and some discharging another. This change brings in a factor that alters the situation entirely.

The lack of importance of the individual compared to the race

The cells of a feather, or of the skin, or of a leaf of a tree are evidently incapable of forming a new bird or bat or oak. They are specialized or differentiated, as we say, for a particular purpose, and what is true of them is true of the body of the individual as a whole. Yet the original tendency, which we saw in the microbe or the amœba, persists. That tendency was to grow and grow, until the only way in which yet further growth could be attained, and more life achieved, was by cell-division.

And this tendency to cell-division, and the birth of new life, persists in oak or man no less intensely and inevitably than in bacillus or amœba. In every living species whatever, this making of more and more life is the dominant need and purpose; and the key to death is that it is only the passing of an individual, not of the race, and that it is better for the race that the individual should pass away.

This is what we must now try to make plain; and to that end we must ask ourselves what the individual is, from the point of view of life as a whole.

If we look at the simplest individuals, such as a bacillus or amœba, the race is simply a succession of such individuals, and it is impossible to distinguish between the life and interests of the race and the life and interests of the individual, since these forms are single-celled organisms and consequently the propagation of the race, which, as we shall see, is carried on by single cells, requires all of the individual for that purpose. But directly we go any higher, we find that only a tiny part of the individual is set apart for the future. Such parts are called the "germ-cells"; and they perpetuate the race. The individual's body is not the race; it is the temporary representative of the race, whose business is to take care of the germ-cells, or cells of the "germ-plasm," intrusted to it, and hand them on unhurt to the future. When that has been done, the individual has performed his or her task for life, and may disappear. Indeed, the individual *must* disappear, as we shall see, if the best interests of life are to be served, and its death therefore directly serves and extends life as a whole.

This view of the importance, or rather lack of importance, of the individual involves ideas so revolutionary that they require solid proof, and that proof is now presented. Students of life regard Weismann's interpretation as the true one. He pointed out the potential "immortality" of the unicellular forms of life. One must insert the word "potential," since, of course, any living thing can be killed. But these forms of life know nothing of natural, designed, predestined death.

The ceaseless succession of individuals that make up the race

Now, the germ-cells, which are cared for and sheltered and fed in the bodies of individuals of all species above the single-celled organisms really correspond to the sequence of individuals among the amœbæ, or bacteria, while the body of the individual simply shelters the successive generations of the germ-cells. Therefore we may speak of, and recognize, the "immortality of the germ-cells," corresponding to the "immortality" of the single-celled species. Nature, as Tennyson saw long ago, is "careless of the single life," but now we see why. Nature is careless of the single life or individual only because she is careful of the race. She therefore considers the individual only in the interest of the immortal germ-cells of which the individual is the host; she constructs all individuals not in their own interest — as we are apt to suppose — but in the interest of the race and the future.

The unfailing renewal of life which is the first great law of nature

They are not made for themselves, but for parenthood; and, when they have discharged all their duty to the race, they cumber the ground. Let them pass away and their bodies be resolved into their elements, and nourish the future — perhaps even the new individuals to which they have given birth.

If we look at the facts, we find that they justify these assertions, which at first sight seem impossible. The common saying that "self-preservation is the first law of nature" is true only under circumstances wherein the death of the individual would jeopardize the preservation of the race. The preservation not of the self, the individual, but of the race, is nature's first law. If we survey the living world as a whole, we find that self-preservation is subordinate to, and exists in order to serve, the preservation of the race. The unfailing renewal of life — that is living nature's first law. The instinct towards this end, sometimes called "the reproductive instinct," and oftener still, by a most unfortunate misinterpretation of its very essence, called "the sexual instinct," is best called "the racial instinct." It is the instinct requisite for the continuance of the race; and not hunger, but this instinct, in all its forms, is the dominant passion of the living world. In mankind, that unique being, this instinct may take many forms, and may become almost unrecognizable; but whether it remain crude and primitive, as lust, or become transfigured and idealized as love, it has its æonian roots in life's imperative impulse towards more life and fuller.

One of the ways in which it is true that it is love that makes the world go round

Following this dominant impulse, we accordingly find that, everywhere throughout the living world, "self-preservation" takes a second place. In many species the very act of fatherhood or motherhood involves the immediate death of the individual. In any species the certainty of death, the presence of desperate danger, may be ignored when it comes into competition with the transcendent claims of the instinct which maintains the race. We say that "Love makes the world go round"; and of the many possible interpretations of that saying, one at least is wholly true — that the impulse towards the renewal of life is the dominant tendency of the living world.

There is no appeal from the decrees of this supreme necessity

In the long run, and on the whole, it must follow that the individual is measured, and its fate sealed, in accordance with the decrees of this supreme necessity, beyond which there is no appeal. In many species, as we have seen, the fathers die directly their task is done. In others, as the beehive teaches, the males are deliberately killed by the foster-mothers directly they are of no more use to the maintenance of the race. Their further life might starve the next generation. All the food must be saved for the maintenance of the colony; the drones must not be kept another day to consume the stores of food upon which the colony, and

to that extent the race, depends for its existence until the next year. In other cases the fathers are of use not only as more or less mechanical trustees and transmitters of the germ-plasm which has been intrusted to them, but also as unselfish and devoted workers in the interests of their offspring. In species whose fathers have attained this status, the fathers do not die, but live to see and serve their children.

The service of the future which ultimately justifies all our lives

Of course, we are here speaking of the normal and healthy principles of life which manifest themselves in various ways according to the life-habits of different species. The human father who allows his wife to support him, eats his children's bread, and, in a drunken fit, throws the baby at its mother's head, has hardly a parallel in nature. He outrages all her laws, and is in every just sense the inferior of the microbes which track him down at the last and finish him.

And yet our very detestation of such things, and our intense sense of their wrongness, testifies in itself to our unexpressed perception that fathers and mothers — which would normally mean all individuals — are made for the future, and are justified of their own lives by their service to the future. That is nature's judgment with all her creatures, with flower or insect, or bird or fish; and it is none the less significant that our judgment of each other should instinctively conform to nature's, which is millions of years older.

The parental instinct one of the dominant facts of our nature

Yet one more illustration is pertinent Parents often regret that their children requite their love and devotion with such lukewarmness. The man in his maturity, or the boy at school, does not love his mother as she loved him in childhood. The parental instinct is one of the dominant facts of our nature. The "filial instinct," which many among us have come to think should correspond to it, is no part of the biological plan and does not exist at all, though the name has been supplied for it. Children or adults may love their parents, may be grateful to them, may feel tender to the old, but there is here no real correspondence with the feeling of parents for children, or of all normal people for young and helpless life. Indeed, if we nowadays take care of helpless old people, that is not the "filial instinct," but the parental instinct, directed in us towards those in their second childhood.

In a word, nature safeguards the future; she leaves the past to take its chance. In vain does the mother long for the return of such love as she gave her son. That love was implanted in her for the race; but, her duty done, she must be thankful for what love and devotion she can get. To all this there is a tragic side, and in many respects man may better nature here, but the meaning of the facts is clear.

The universal fact of death that exists in the service of life

If we accept this reasoning, we are still faced with another difficulty. Let us put on one side the unique case of self-conscious and personal man, and, considering such forms of life as the oak, the swallow, the herring, the fern, let us ask: Why cannot life be content with individuals, and make the most of them, instead of persistently making fresh starts and destroying her previous attempts? The whole process seems so wasteful, and so constantly self-annulling, as if one wrecked with the left hand what one made with the right.

But let us observe that, with and through and alongside of all this ceaseless succession of birth and death, of effort to make fine forms, and destruction of them when they are made, *life ascends*. Throughout the ages there is a process, a development, which we call evolution, and on the whole the fruit of that process is progress, "more life and fuller." If we look at the steps and stages by which life thus attains what we have agreed to be its evident and persistent purpose, we shall see that it could have been attained, and will in the future be attained, only by the method of finite individual lives, and an endless succession of fresh starts — *some of which may be an advance on anything that has gone before.*

The old French proverb "Youth will be served" is the universal law of life

Only by the method of reproduction can life achieve new forms. Germ-cells vary, and if they get the chance they will develop a certain number of individuals which surpass their parents. Here, and here alone, is the possibility of all progress. All evolution depends upon variation. If there were no reproduction, there would be no variation; and if there is to be reproduction, the reproducers must make way for the reproduced, the parents for the children. As the French proverb has it, "youth will be served." It is the universal law of life, and it is, as we have pointed out, the necessary and fundamental condition of all progress. The paradox which we have called "the survival-value of death" is therefore justified; and we see it to be one of the greatest services — however little recognized as yet — of modern biology to the human spirit to have interpreted death in this truly magnificent fashion, as the servant and ally of life and the handmaid of progress. If new forms are to come, old forms of all plants and animals must make way for them, good though those forms may be in themselves, and better than any that went before them. They have not existed in vain, though their lives seem so short, and though they might incline to ask, if they could, why they were born merely to die.

The living were not born to die, but to beget better life

They were not born merely to die. That is not the purpose underlying life. On the contrary, they were born in order to beget better life than their own, in order to serve the future and take another step towards realizing the utmost that shall be. And since individuals, however ephemeral, are thus necessary for her purpose, nature rewards them well, makes life sweet, and the renewal of it and devotion to it sweeter still, and hides completely from them the knowledge of death. So pleasant, indeed, does she make even this terrestrial portion of life allotted to her self-conscious marvel, man, who can foresee death, and taste its agony afar, that even this life is well worth while, and "a pleasant thing it is for the eyes to behold the sun."

Lest the reader should not have given the intended weight to those qualifications which the fear of lending color to unscientific materialism has required us to make in the foregoing statement of physical death, let it be most clearly laid down now that we have here been considering death as a terrestrial fact, a fact actual, indeed, but physical, essentially material, and of things seen. It is the common lot of all forms of life, high or low, admirable or horrible. Certain dispositions of matter, which we call their bodies, cease to exhibit former powers, and fall to pieces.

The everlasting mystery that lies beyond physical death

That is the evident fact of physical death, of which the foregoing is the interpretation offered by modern science. The only death that physical science knows is physical death — death of the body. That apparently wasteful and cruel process is here interpreted as being a necessary condition of the coming of finer and higher bodies in the future.

But of the death of that, whatever it be, which animates the bodies of living things, science has no record or evidence. It only knows, what all men know, that bodies in which life showed itself fail to display life longer, and fail even to maintain their form and structure. That is death, the only known death, and that death science seeks to interpret. But those who, greatly presuming, looking only on the material surface of reality, and thus profoundly ignorant, would infer from the bodily disintegration which we call death that nothing beyond remains, have yet to pass through science or "knowledge" to wisdom, which knows, as Socrates said, *what it does not know*. "Where shall we bury you?" they asked him, before the executioner came. "Where you will," was the reply, which has survived the ages, and will survive infinite ages more, *"if you can catch me!"*

From Montgomery's *Productive Farm Crops*, J B Lippincott Co

OATS HARVEST IN NEBRASKA

Available soil water is often the controlling factor in paying crop yields

Courtesy Planet Jr Co

CULTIVATION OF COTTON

Cultivation not only aërates the soil and keeps it free of weeds but often prevents the loss of soil water by surface evaporation.

THE WATER OF THE SOIL

The Wonderful Adventures of the Rain as it Wanders through the Realm of the Soil

SOIL MOISTURE A SERVANT TO THE PLANT

WATER is an all-pervading element in the soil and has a part in practically all of the actions therein. So universally present is it that it really should be listed as one of the constituents of the soil. It is necessary in all phases of weathering and above all it is absolutely essential for plant growth. It functions outside of the plant as a solvent for food and as a carrier of this food to the rootlets. The importance of this carrying function becomes apparent when we think of the many millions of particles and the comparatively small number of rootlets. Only the portions of these near the tips have absorbing power and it is plainly impossible for them to come into contact with every particle that is giving up material to the soil water. Remember again the immense internal surface of the soil which is free for solution. Do the plants not need a nimble waiter to convey the food to their hungry rootlets?

Water is taken up by the plant in large quantities and once it is inside it has a further work to perform. It still acts as a waiter, carrying food back and forth as it is needed at various points whether in root, leaf, or stem. It keeps the plant turgid and upright. When a plant does not have plenty of water it wilts. Water evaporates from the leaves in immense quantities and tends to keep the plant cool. It also is a food and when broken up it serves as a source of oxygen and hydrogen. It is a determining factor in crop growth and must be carefully controlled in successful agriculture. In the soil or in the plant water is the servant of the crop growing on that particular soil.

The amount of water required by plants

If you should set a tumbler over a small plant you would find that the inside of the tumbler quickly becomes damp and cloudy due to the moisture that has settled on it. Where has this water come from? Evidently from the plant. The plant is constantly giving off water from the openings in its leaves and, as might be expected, the amount lost in the course of the growing period is very great. As this loss is necessary for the normal growth of the crop and as it must be furnished from the soil it behooves us to look a little further into the question.

The amount of water used up in this way is most conveniently expressed in terms of pounds of dry crop. The pounds of water necessary to grow one pound of dry plant tissue are usually given. It is the ratio of the water used to the crop produced. The ratio for corn is 270, for wheat 340, and for oats 500. Think of it, five hundred pounds of water used to produce a pound of oats! One and three-quarters million pounds of water to grow a thirty bushel crop! Can the soil ever provide such untold quantities? It evidently can, as we grow crops. Let us inquire into the wonders of this service.

The kind of water in the soil

The soil water circulates through the large and small pore spaces, which make up from thirty to fifty per cent of the soil volume. Because of the relationship of the water to the soil particles, we have two kinds. One kind, the "film water," exists around the particles.

If you dip a marble, such as boys use, into water you will find that it assumes a thin coating of liquid. This is similar to the film water of the soil. The other kind of water is found in the very large pore spaces and moves downward by the force of gravity. It is called the "free water." It is the water that runs through and out of the soil. The film water is that which remains and keeps the soil moist.

Film water

The film water surrounds the particle as a coating of variable size. Sometimes it is thick and sometimes it is very thin. Part is held but loosely by the soil particle and part, that in immediate contact with the soil grain, very tightly. The outer portion may be lost by evaporation at ordinary temperatures.

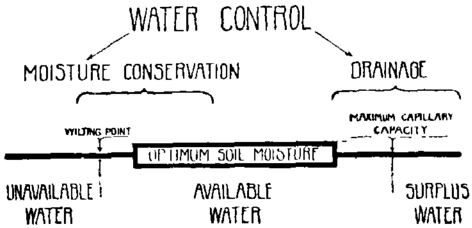
This water has to do very largely with the solution of plant food It is in contact with the particles, and it is in this film that the principal chemical actions take place. As it is full of nutrients it is evidently the moisture which is sought after by the rootlets. If so, it must have movement The roots, as already shown, must be served. They must be waited on If this water performs this service it must move and move with considerable ease to satisfy the urgent and immense requirements of the plant. Water is inanimate and so are the soil particles. How does movement take place, and why does it take place always in the right direction?

Suppose you suck some water out of one side of a glass. Is there a hollow left at this point? No, the water flows in from all sides and immediately fills it up. It always maintains a level surface, no matter how much you may withdraw at any point. The water in the soil acts in the same way in that it tries to maintain the same thickness of film in all parts of the soil Water flows quickly from the thick to the thin films. Suppose now that a rootlet withdraws some water at a particular point. The film becomes thinner, water flows in from every side, and the plant is furnished with new dishes and fresh food. The plant gets new supplies by using up what is already before it.

Free water

If water is added to a soil, the first portions are absorbed and held as film water. As the addition continues the films come to their maximum thickness and no more moisture can be absorbed in this way. Water then collects in the large pore spaces of the soil. As the friction with the soil particles is small it responds to the pull of gravity, and moves downward, at last appearing as drainage or free water. It is this water that we see running out of tile drains, seeping out of banks and rushing along open ditches.

This water does not come in such close contact with the soil particles as does the



From Lyon's *Soils and Fertilizers*, The Macmillan Co

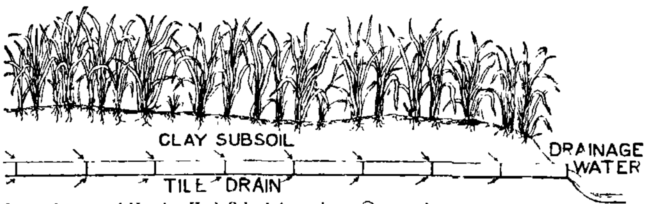
THE ELEMENTS OF SOIL WATER CONTROL

Moisture control consists of conservation or addition of water on the one hand and drainage on the other The farmer's major efforts, once the crop is on the land are towards the maintenance of an optimum moisture condition in the soil

film water, nor does it usually stay in the soil very long. It therefore is not of much use to the plant rootlets. In fact, it is actually harmful, as it stops up the large spaces in the soil through which air passes When air is shut out of the soil, plants as well as bacteria must suffer. It behooves the farmer to have his soil in such condition that this free water may drain away quickly. The physical, chemical, and bacterial condition of the soil is much benefited by such a movement and the soil becomes much more efficient as a laboratory for the preparation of food. Drainage by means of open ditches or tile drains will accomplish this. Good deep plowing by loosening up the soil is a great help. All the forces which promote granulation aid in quickly releasing the soil of this moisture burden, which hinders so seriously the proper growth of crops.

Available soil water

It has already been stated that the free water of the soil is superfluous. In other words, the soil is better off without it. This leaves the film water to meet the immense demands of the plant. We have already seen how great these demands are and how the film water is able to move in response to the crop needs. This film moisture may amount to two or three million pounds per acre on an average soil. Certainly this should be enough to grow any ordinary crop.



From Mayne and Hatch *High School Agriculture*, © 1913, American Book Company
WATER SEEPING INTO THE DRAIN
Diagram showing how a tile drain tends to remove the excess water from the soil. Such removal should be rapid.

Unfortunately this moisture cannot be all used by the plant. The forces which hold it around the particles are so strong that only a part can be drawn away by the plant roots. From one-fourth to one-half is beyond the reach of the plant and is therefore called "unavailable" water. The part of the film water which is taken up by the plant is called the "available" moisture. Three kinds of water, then, exist for the plant — unavailable film water, available film water, and the drainage or free water.

Optimum moisture

If you are growing a crop what kind of moisture do you want present? Evidently available water, since it is the form that waits on the plant, serving it with the necessary food. But before thick available films can be present the thin unavailable films must exist also. As a consequence enough water should always be present to insure the thick film moisture and yet not so much as to cause the free and harmful water to clog up the pore spaces and shut out the air.


From Lyon and Fippin's *Principles of Soil Management*, The Macmillan Co.
LAYING A TILE DRAIN
A tile drain performs two functions. It should collect the water from both sides and discharge it quickly from the soil

As far as the soil moisture is concerned the farmer is always trying to do one thing — maintain plenty of available water in the soil. This right amount of moisture is called the "optimum moisture content." It is important in that it is the best percentage of water for all soil activities whatsoever. Granulation takes place better at this moisture content, chemical changes are more rapid, the bacteria work faster, and of course the crop growing on such a soil does better. This optimum moisture is maintained in two ways, by draining away the free water if it is present and by conserving or even adding water if the available moisture begins to run low. Drainage and moisture saving are the two important practices in moisture control.

Drainage

Since the free water shuts out oxygen and at once sets up unsanitary conditions in the soil, its removal is necessary. The operation is called "drainage." While there are a number of different kinds of drainage only one need claim our attention, since it is the best and most generally used. This is tile drainage.

Land tiles are round or six-sided pipes about a foot long, and from three to fifteen inches in diameter. Trenches are dug in the land a little below the plow line with plenty of slope towards the lower end or outlet. In such trenches are laid the tiles, end to end, making a smooth channel from the upper to the lower end of the ditch. The trench is then filled in. The outlet is protected so that it cannot become stopped up.

The water enters the drainage system through the joints between the tiles. These joints are too narrow to let in the soil but quite large enough to admit the free water. Once the water is in it merrily races away towards the outlet and the soil is freed from its load of superfluous moisture. In order to drain the land thoroughly, strings of tiles are often laid at regular intervals, usually about fifty feet apart. Sometimes they all empty into one large string, which is called the "main." Thus the water from one or more fields may be discharged at a single outlet.

From Lyon's *Soils and Fertilizers*, The Macmillan Co.

OUTLET OF A TILE DRAIN

The protection of such an outlet is vital in the successful and continuous functioning of a drainage system

The tile drain is a very efficient arrangement, and a great deal of our land needs such a system. In digging the ditch, laying the tile and protecting the outlet we are apt to think that drainage is as commonplace as it is useful. Keeping in mind the benefits of drainage already cited, read this little poem by Professor Bailey of Cornell University. It pictures the silent faithfulness and the wonderful influence of the lowly drain tile.

Far under the ground
As men pass by
Unseen and alone
I silently lie.

I feel the cool earth
And the slow trickling streams,
And roots of big trees
That pry in my seams;
And crawling things find
When pursued by alarms
A welcome retreat
As they hide in my arms.

The cattle I hear
As they move on the land,
And the burrowing folk
That build in the sand.
When the plow-team tramps
On the full crunching earth
I feel the hard thrusts
Of the first harvest birth;
But the plowman thinks not
That I lie down below
And tireless prepare
For the harvests to grow.

Years in and years on
I rest in my bed
And draw down the rains
When the farmer is dead;
And nothing I care
That the people know not
Whether I am
Or where is my lot.
All secrets I hold
Of the dead and the live,
For they all come at last
To the soil where I strive.

Calm and content
I silently lie
And carry my work
As men pass by.

The saving of moisture

Methods of getting rid of the free water have now been discussed. Let us look for a moment to the means of conserving the available moisture of the soil. It is not unlimited in amount, and economy would be necessary even if it were all used by the plant.

Unhappily only a part of the available water gets to the plant. A large amount is lost by evaporation from the surface of the soil, moved upward by the same forces which carry it to the rootlets. By cutting off this loss, just that much more water can be used by the crop. This is what is meant by moisture conservation, a practice of great field value.

HOW MULCH PRESERVES MOISTURE

From *Soil Science*, H. Dunham C

COFFEE RISING THROUGH SUGAR

COFFEE DOES NOT RISE THROUGH LOOSE SUGAR

A demonstration of the principles that make a soil mulch effective. Coffee rises rapidly through the compact lump sugar but moves but slowly into the loose layer placed on top

From S. W. Fletcher's *Soils*, Doubleday, Page & Co.

MULCH

Under the dry soil mulch are found the moist layers bearing abundant available moisture

If a board is laid down on the surface of the soil, the earth underneath it will in a short time be quite moist. This is because the board shuts off evaporation and the soil

From Lyon's *Soils and Fertilizers*, The Macmillan Co

THE ILL EFFECTS OF EROSION

When too much water is removed from the soil over the surface serious damage results The control of such erosion is an important phase of soil management

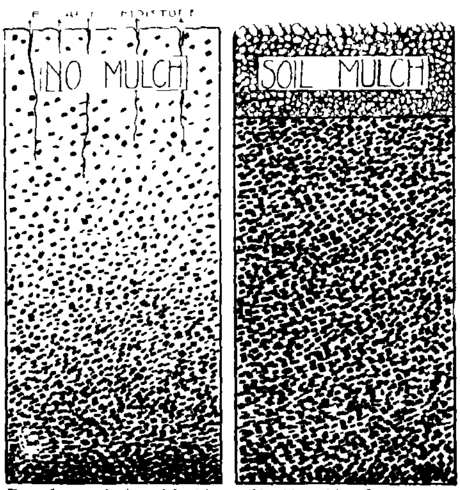
at the surface comes to the same moisture content as the lower layers Can we in some economic manner cover the soil with a layer of material and thus shut off the great loss of moisture?

In applying this idea the farmer has hit on the practice of covering the surface with a dry layer of soil. Is this layer hauled in and spread over the field or garden? By no means. The layer is formed in place. The field is simply harrowed or tilled in some other manner and a layer two or three inches deep quickly dries out. This dry covering is just about as effective in conserving water as though boards were used and it has the advantage in that it does not interfere with the growth of crops. This layer of dry soil is called a "mulch" and is much used with intertilled crops such as corn and potatoes.

In humid regions this mulch must be renewed after every rain. It is usually only two or three inches deep, as this thickness is quite sufficient to check moisture loss. It has other good effects besides the saving of moisture. Its formation keeps the soil loose, open, and well granulated. Air can circulate readily. Rain is made to enter the soil and its washing effects are prevented. Weeds are killed when the mulch is renewed. In arid regions the mulch is used to store water from one season to another. In humid sections its value lies in carrying the crops over periods of drought Under any condition it is important in the control of soil moisture and in the killing of weeds.

Irrigation

In some regions the preservation of the moisture received by the soil as rain is not sufficient to grow crops Water must then be added artificially This is called "irrigation" and is commonly practised in our arid West The water used for this purpose comes in large part from the streams, being diverted by dams and run through canals to the land One large canal may supply water for several thousand acres The water is usually run on the



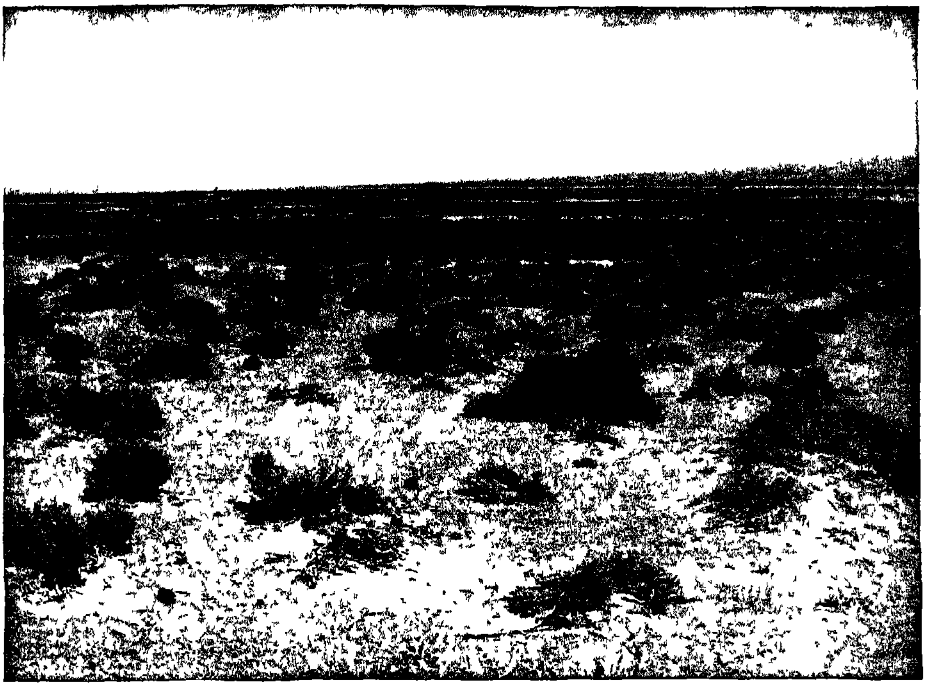
From Lyon's *Soils and Fertilizers*, The Macmillan Co

DIAGRAM SHOWING HOW A SOIL MULCH FUNCTIONS

By stopping the upward movement of the water the dry layer successfully reduced evaporation losses

soil during the growing season and while a crop is on the land. So distinct a type of agriculture is irrigation that many books have been written about its various phases. As might be expected there are a number of different ways of adding this water.

THE MIRACLE OF IRRIGATION



THE DESERT BEFORE IRRIGATION

From Newell's *Irrigation Management* D. Appleton Co.

THE SAME LAND AFTER PROPER IRRIGATION AND CULTIVATION

TWO SYSTEMS OF IRRIGATION

From Olin's *American Irrigation Farming* A C McClurg & Co

THE IRRIGATION OF POTATOES

This method of applying the water is known as the "furrow system" and calls for good judgment and skill on the part of the irrigator.

From Widtsoe's *Principles of Irrigation Practice*, The Macmillan Co

IRRIGATING CHERRIES IN CALIFORNIA

The method of irrigation being utilized here is called the "check system."

Irrigation water may be applied in several ways. The most common practice is to let it either flood over the land or trickle down the furrows between the rows. The former method is used with wheat and hay, while the furrow system is a common one with corn and potatoes. Sometimes the water is sprinkled on from pipes hung above the land on posts or wires. Such a system is called 'spray irrigation."

From *Soil Sense*, The Dunham Co.

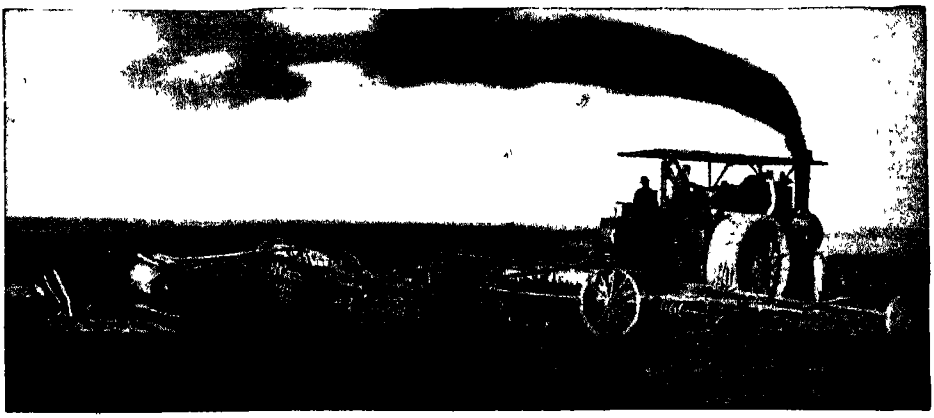
SOIL MULCH AND ITS CROP RELATIONSHIPS

Note how the roots are developing in moist layer below mulch

Irrigation is sometimes practised in humid regions such as the eastern United States. This is peculiar Why is it necessary? We remember that the soil mulch is used to tide the crop over a dry period. Suppose this dry period is unusually long, that the soil is too light to conserve water well, and that the crop is very valuable Under such conditions would it not pay to install an irrigation system? We are finding irrigation, therefore, becoming more and more useful in humid regions especially on soil given over to gardening and other intensive cropping.

Soil moisture control

It is clearly seen that moisture in the soil is a vital factor in plant growth, and as moisture may be too large or too small some control is necessary. This control consists in drainage on the one hand and conservation and irrigation on the other. All of these practices attempt to maintain in the soil, at least while the crop is growing, an optimum degree of moisture. Do farming operations now seem so haphazard? Is not there order and reason in it all? When we look at the question in the light of science and common sense, farming assumes an interest quite unlooked for and unexpected. The why of anything is always a source of interest.



PLOWING, HARROWING AND ROLLING LAND AT THE SAME TIME

THE TERRIBLE KING OF BEASTS—HOW THE LION SPRINGS UPON HIS PREY

In securing his food, the lion has recourse to cunning, stalking skilfully, and displaying marked cleverness in taking advantage of the least cover. When near enough to trust to his speed for the final dash, he hurls himself at his prey, grips the victim with his forepaws, and inflicts a crushing bite upon the back of the unfortunate's neck. A bite at the throat follows, to secure a deep draught of blood, not to kill, the first wound usually depriving the victim of all power to resist.

THE ANIMALS OF TERROR

Some Members of the Great Cat Family — Life and Habits of Lions, Tigers, Leopards, Jaguars, Cheetahs

THE FEARFUL BEASTS THAT FEAR ONLY MAN

MADAME DE STAËL once declared that the more she knew of men the more she admired dogs. The student of nature, on the other hand, is impelled to admit that the more he knows of the flesh-eating animals, the great carnivores, the more he admires man.

The Carnivora are creatures of enormous physical strength and with superb weapons of offense and defense, making them the most terrific instruments of destruction in animate nature. By every law of probability the human family should have disappeared entirely before them. The Carnivora have lived through the ages entirely by slaughter.

Yet in the presence of this vast devastating host, ranging almost the entire world, man, by his cunning and courage, has achieved supremacy. He still pays heavy toll in human life to these ferocious captains of the wilds; never a day passes in which somebody in the African forest jungles is not killed and eaten. But the victory is as a whole with man. The lives now lost are as those sacrificed to snipers through whose country a victorious army is marching. We may consider ourselves spectators of the closing phases of this contest, ages old, between man and the beasts of prey. The time must come when the last free lion and tiger and leopard will have to be slain. Civilized man cannot live in company with the great cats. The man-eaters are bound to go, as surely doomed as were the wolves which ravaged the early settlers' homes long ago. In the meantime in Africa, Asia and America the great cats are making as fierce a fight against conquering man as ever.

The scene is the same, though its boundaries are constantly being narrowed down before the steady advance of civilization. Man now has firearms instead of the primitive weapons with which his ancestors fought, but today the unarmed man is as helpless before lion or tiger or jaguar as were the earliest men. Indeed, perhaps he is a little more powerless, for civilization has made him forget how to fight with natural weapons. In contests such as these the conditions are unaltered from those in which the first puny men matched themselves against the ferocity and strength of the flesh-eaters. The death-roll is grievously heavy, but it is perhaps strange that it is not heavier still. In the last resort the great cats do not fear man. In the abstract they do. If they reason it out at all, they may possibly associate his presence with the presence of their greatest terror — fire. They have certainly learned to discriminate between an armed man and one unarmed; and this is nowhere more conspicuous than in India, where the tiger snaps up a native, yet skulks — in the daytime, at any rate — from the man behind a gun.

With all his insensate savagery, the lion, now that one of his great provinces has been wrested from him, commands a sort of sympathy. India has become the grave of almost all the race of lions that peopled its jungles and its stony plains. The animal has been practically exterminated throughout the country; a few, however, are now carefully preserved in that portion of Kathiawar known as the Gir Forest, and it was stated a short while ago that even there only half a dozen still remained. But

there remains a great part of Africa, from Cape Colony to Abyssinia and Algeria; and in Asia the lion claims Southern Persia and Mesopotamia for its range. We still call it the "king of beasts," for, while it lacks the impossibly noble qualities with which man was once wont to invest it, there is no other animal that can be so exalted.

No other beast can compare with the lion for splendor of appearance. This applies, of course, to the great maned lion, which, by the way, is seen at its best in captivity. It would seem as if life in the cage encouraged the growth of hair, so that we get a false notion, from the appearance of the menagerie lion, of the figure that he presents in the wilds. But even in its natural state the appearance of the lion is impressive enough. The mane and ruff serve not merely as adornment: they constitute an armor to defend the neck and throat of the lion in battle with other carnivores.

The battles between lion and tiger which may have driven the lion from India

This protection must have been necessary for the Indian lion in such battles as he fought with the tiger, for, though the lion looks a bigger and stronger animal than the tiger, the tiger has the advantage in jaws and claws; and such evidence as we have of battles between the animals goes to prove that the tiger is generally victorious in combat. Indeed, it has been affirmed that the disappearance of the lion from India is in part due to tigers.

In making this comparison between the two animals it should be remembered, however, that it is in Africa, from which continent the tiger is absent, that the lion reaches its maximum strength and size. Even the African lion, however, would stand but small chance with the largest of the tigers — the Siberian variety. It is a little difficult to arrive at any definite knowledge as to the actual bulk of either animal, however, for weight has to be reckoned and proportions measured in the wilds where the killing takes place. Still it is safe to say that lions weighing over 500 pounds and measuring ten feet from the muzzle to the tip of the tail are not uncommon.

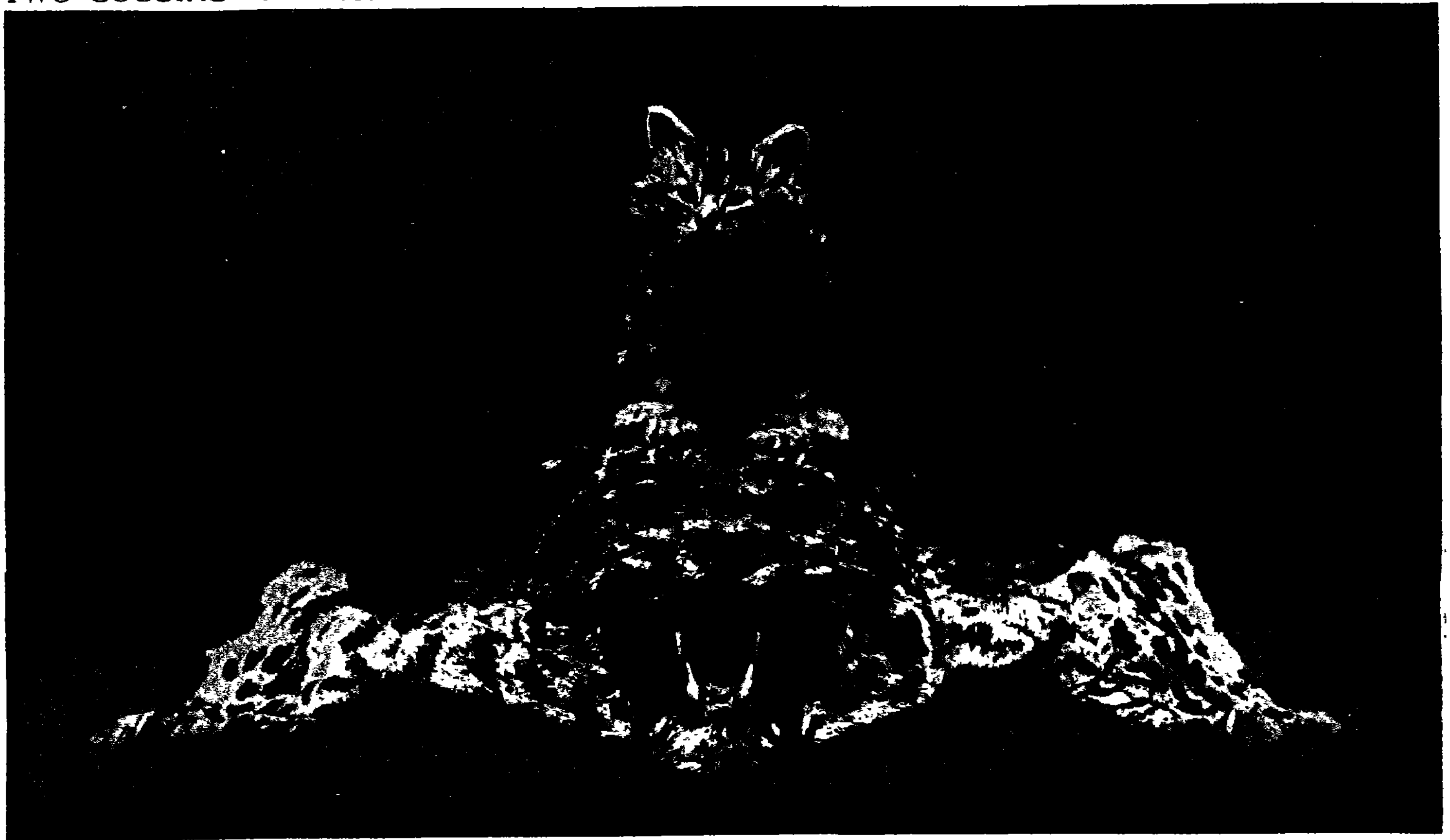
One feature the king of beasts possesses unchallenged — his voice. When lions roar in chorus, as they are accustomed to do when rival troops approach the same water-hole, the very ground is shaken; and the effect upon a listener, lying chilled and apprehensive in a veldt camp, is more impressive than anything else the big-game hunter knows. The fact that the lion, like all the other Carnivora, is a night animal, and roars only when man is abed, makes his solemn, deep-chested notes the more awe-inspiring.

The terrible way in which the lion attacks its victims

The food of the lion varies with his habitat. In the oak forests of Persia, the wild pigs furnish an abundant diet; in Africa, the zebra, the hartebeest, the giraffe, the antelope, and, more rarely, the buffalo, is the staple food. The teeth are the lethal weapons, not the mighty claws. It is commonly supposed that the paws are used to kill, but as a fact they are only the gripping instruments. Men have been killed, no doubt, by a blow in this manner, but not necessarily by design of the lion. As a cat claws at a mouse which moves, not to kill, but merely to retain it, so the lion strikes with his sledge-hammer limb at head or leg or hand which his victim moves. In attacking animals he does not, as a rule, spring boldly upon his victims, as pictures commonly represent. He rears himself into an almost upright position, and, while standing on his hind legs, grips the animal with his forepaws, and inflicts a fatal bite at the back of the neck. This he follows with a deep bite in the throat, apparently in order to drink of the victim's blood, as the bite is not necessary to kill, the blow from the mighty paws having already destroyed all power of resistance.

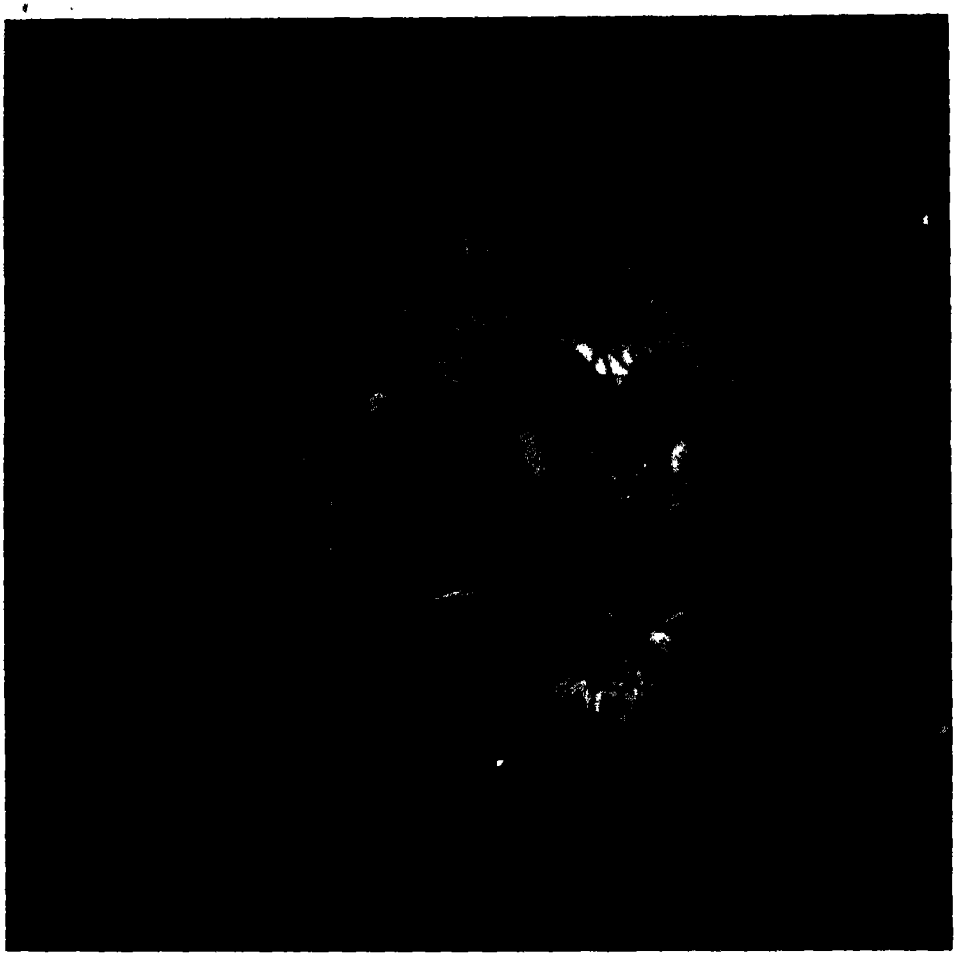
The fear of man which the great cats commonly experience is observable in the day rather than night. The contempt which a lion shows for man after sunset suggests that the camp-fire may be the actual cause of his fear, but even the camp-fire fails at times to stop the determined man-eater. How the lion takes to man-killing it is always difficult to say.

TWO COUSINS—THE LITTLE TIGER OF THE HOME AND THE GREAT CAT OF THE JUNGLE



The domestic cat is merely a lesser tiger; the tiger is one of the largest cats. This photograph of a kitten perched on the head of a leopard shows the close resemblance between these vastly different members of the same family.

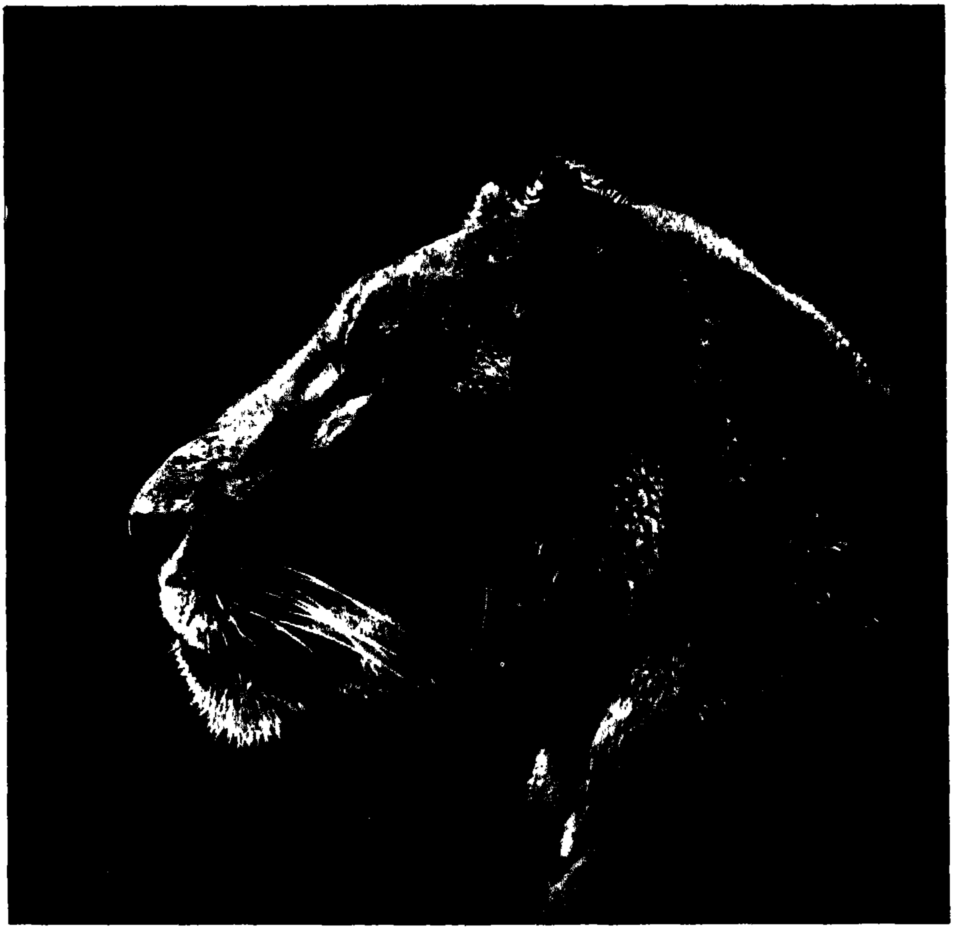
Some of the photographs in these pages are by Mr. W. P. Dando and by Mr. Gambier Bolton, Mr. Bolton's being reproduced by permission of the Autotype Fine Art Company.



THE HANDSOME HEAD OF THE GREAT MANED LION, WITH WHICH NO OTHER ANIMAL CAN COMPARE FOR SPLENDOR OF APPEARANCE

The usual supposition is that the animal resorts to the quest of man only when his speed and strength are waning, so that fleeter game passes beyond his reach. That, however, was not the fact concerning the man-slayers at Tsavo, whose depredations actually brought the building of the Uganda railroad to a halt. These animals were neither old nor decrepit; they did not lack other food, for large flocks of sheep and goats, together with other animals, surrounded the works. But night after night one or both of the brutes crept silently into camp, avoided all traps, and eluded watchers lying in wait to receive them with guns. And at every visit a man disappeared.

These animals certainly displayed greater skill and rapacity than Livingstone would admit as the attributes of the lion, but the varied experiences and observations of travelers compel us to believe that lions differ in character as much as dogs and horses. While some are stupid and cowardly, others display considerable cunning and invincible boldness. The man-slayers of Tsavo turned the tables on their hunters, and so did another fierce brute whom three men set out to kill at Kiu, when the railroad was being built in British East Africa. The hunters ran their sleeping-car onto a siding, and sat up one night to watch and wait. The night was dark, with little moon.



THE AFRICAN LIONESS WHICH HAS NO MANE AND IS PROBABLY THE MOST FEROCIOUS BEAST ON THE FACE OF THE EARTH

But about midnight one of the party remarked to the others upon the brightness of the "fireflies" near the car, and noted also that a rat repeatedly crossed and recrossed a spot where a steel rail glinted in the moonlight. But the "fireflies" were the eyes of a lion, and the "rat" was its tail dragging across the rail as the animal moved slowly to and fro. The lion was stalking its hunters. Towards morning the three men dropped off to sleep, one sitting upright with his back to an open window. Suddenly the lion sprang into the carriage, seized and worried him in the presence of his horrified companions, then leaped out through the opposite window, carrying him in its mouth.

As grim an experience was that of Mr. Ernest Brockman near Kota-Kota in Central Africa; a lion broke into his tent at night, seized him by the shoulder, dragged him out of bed, carried him thirty yards away, and deposited him under a tree. Then, though natives were firing right and left, and torches were gleaming in all directions, the brute lay down by its victim, and drank his blood. Each time the man moved, the lion bit him. But he did not yet seek to kill; he bit only in order that he might drink blood, and he continued at his awful work long enough to enable a friend of the victim to get up and shoot the lion dead. Mr. Brockman was rescued in a terrible plight, with twenty-one bad wounds.

The courage of the lion, never in dispute when the animal is brought to bay, becomes a sort of frenzy when he is wounded. The spring of 1911 brought a tragic instance of this, involving the terrible death of George, brother of Sir Edward Grey, the English statesman. Sir Alfred Pease's ostrich farm at Athi River had for some time been harried by lions. A hunt was organized, two big lions were driven from their hiding-place, and one of these turned to charge. George Grey dismounted and fired a shot into the animal's shoulder. This did not stop him, so he fired again, the second shot smashing two of the animal's fangs and seriously injuring his lower jaw. But the lion charged home, knocked his victim down, and mauled him horribly. The other members of the party now rode up, and the lion turned to face them. A third bullet was put through his ribs, but he returned to Mr. Grey, and, as an eye-witness said, "worried him just as a dog worries a rat."

A dying man without pain in the grip of a lion

A fourth shot was necessary to finish the monster. George Grey was frightfully mauled, yet he seems to have felt no pain, for he was perfectly calm and cool, and able to advise his horrified friends how best to handle his lacerated body. Unhappily, however, the after-effects of his injuries were so serious as to cause death.

It is sometimes asserted that the lion is less wantonly cruel than the tiger, and that it will not kill for killing's sake. There is little in the theory. Lions are as savage in instinct as the pet cat which, after being fed with delicacies, will go into the garden and kill, for sheer lust of slaughter, birds which it makes no attempt to eat. Mr. J. G. Millais encountered a lion which at various times had eaten half a dozen native women. It was neither old nor feeble; it was a ten-foot lion, in the prime of its vigor and speed. It visited his camp one night and struck down a donkey within five yards of his camp-fire. Two other donkeys broke away in terror. The lion left his first, and pursued them, slaying first one and then the other. It ate the third.

The terror of life in the country haunted by tigers

The tiger is more destructive of human life than any other animal in India, in spite of the fact that hundreds upon hundreds of tigers are slain there every year. But while the tiger is the animal for which India is notorious, its range is by no means limited to that country. It flourishes throughout a great part of Asia and its islands; and in places such as Java and Sumatra it is sufficiently numerous to affect the commerce of the world. So serious are its ravages at times that the supply of coffee is periodically curtailed owing to the tigers infesting the route from the interior to the coast. In India, however, its depredations are such as to wipe out entire villages. Not that it kills every one of the inhabitants; but it kills so many that the remainder dare no longer stay. Many deserted villages are to be found whose populations have been thus in part destroyed, in part driven away by these terrible beasts. The number of deaths caused by tigers in India was in three successive years 909, 896, and 853. In the same period nearly 5000 tigers were killed. Seeing that tigers claim a great share of the 90,000 cattle destroyed by wild animals in India every year, it is not to be disputed that the natives pay dearly for their unwilling hospitality to this ferocious animal.

It is among the natives that the tiger finds his victims; he distinguishes readily between the defenseless Hindu and the armed white man. The native who tends cattle in tiger-infested country sees many of his charges disappear before he himself is attacked. Then, some day, something unusual occurs. Either he provokes the tiger to rage by attempting to balk it of its prey, or the tiger is indisposed to tackle a bullock. He attacks the man, and then the worst has happened. There seems no doubt, as concerning the tiger, that, "once a man-eater, always a man-eater" is the rule. Man, so long dreaded or avoided, proves even more vulnerable than the cattle, and man becomes the diet of that tiger. Thus we find that the human victims of a single tiger often run to scores.

CATS OF THE OLD WORLD AND THE NEW

THE LITTLE KNOWN SNOW LEOPARD, WHICH HAUNTS THE MOUNTAINS OF CENTRAL ASIA

THE PUMA, THE GREAT AMERICAN CAT WHICH DEVOURS CATTLE AND HORSES

The snow leopard, or ounce, is a mountain-haunting cat of Central Asia. Owing to the inaccessibility of its home the habits of this animal in a state of nature are comparatively little known. The puma, one of the two great cats of America, is said to be friendly to man, but terribly savage to horses and cattle.

There is very little difference between the habits of the lion and the tiger, and very little difference in structure. The distinction is chiefly on the surface. The tiger is striped, the lion is not. The tiger is not maned, and he lacks that tuft of hair at the end of the tail which distinguishes his cousin. Except that the tiger is lower on the legs and slightly longer in the body, the differences as to structure are less notable than the resemblances. In habits the two beasts are closely akin, although the lion

AN HEIR-APPARENT OF THE ANIMAL KINGDOM

The lion cub, not yet having attained to the dignified mien of the king of beasts, looks, and is, a frolicsome beast, easily tamed, and quite safe until accident reveals to it its physical superiority over man. Its play, when wild, is a natural training for the fierce encounters of its maturity.

apparently likes the company of his own species more than does his striped kinsman, who prefers his own society, associating with the female only at certain parts of the year.

How is it, then, that the tiger abounds in every jungle and in every extensive patch of reeds and grass, while the lion has been exterminated? One answer has already been given. Another is that the tiger is less restricted in choice of shelter than the lion. The latter has no "den," but the tiger has.

While the tiger will make his home in the jungle or in high grass and swamps he is equally at home in caves or clefts of rock, and among the ruined buildings of deserted cities. He is perfectly comfortable, too, in pestilential districts into which white men dare not penetrate. His sanctuaries, therefore, are manifold. But the curious thing is that, where one tiger has been, another is certain to follow after the first has been destroyed. The tiger occupies his predecessors' haunts as surely as mice and rats take up their residence in holes where other mice and rats have been.

A good swimmer, the tiger covers a wide range in his immediate neighborhood, swimming out to an island by night, and returning to shelter before dawn. He is essentially a nocturnal animal, and dislikes heat even more than the rest of his family.

The natives of India make little attempt to combat the ravages of the tiger. They commonly surrender their cattle, knowing that, if they fail to do so, ill may befall them themselves. To show from what a remote cause tigers may take to man-killing, in 1909, there occurred a cyclone and tidal wave in the Sundarbans portion of the Khulna district, in Bengal, and many deer were drowned. Consequently, there was a smaller supply of food for the tigers which swarm in this district. They took to killing human beings in default, and the return of deaths in 1910 was unprecedentedly high for the district.

In the cat family the leopards come next in importance to the tiger. Though smaller than either the lion or tiger, they are certainly little less to be feared. The tiger makes a prodigious upright leap in pursuit of a man who has sought safety in a tree, but the tiger cannot climb; neither can the lion. The leopard, however, like its cousin the jaguar, is a magnificent climber. It is common to Asia and Africa, and is generally distributed throughout most parts of India. Over fifteen thousand leopards were destroyed within three years, but they caused the loss of over a thousand human lives in the same time. These figures do not, however, represent anything like the number of encounters with men in which the leopard is involved.

PHŒBUS APOLLO HARNESSES THE LIONS TO THE CHARIOT OF THE SUN

Apollo, called Phœbus (the "brilliant one"), is recorded in Greek mythology as having driven the chariot of the sun. He occupied a high place in the Greek Pantheon, and his oracles, notably at Delphi and Delos, were held in the highest respect over the ancient world. — From the painting by Briton Rivière.

The leopard is really a greater menace than the tiger, inasmuch as it more frequently attacks human beings, not always with fatal results. It haunts villages persistently, killing and carrying off ponies, donkeys, cattle, sheep, goats, dogs, men, women and children. Dogs, curiously, are his favorite prey; and there are parts of India in which he has not left a single dog.

While he will attack a man with less provocation than will a lion or a tiger, the leopard also shows much greater boldness in broad daylight, nocturnal animal though he is. Sir Edward Bradford in Rajputana once invited forty Europeans to a picnic and these, with a numerous staff of servants, were assembled at the base of a small cliff. Sir Edward had two white terriers with him; and one of the guests, happening to look up, saw a leopard peeping down at the dogs from a point a hundred and fifty feet above. Sir Edward was warned that the big cat had designs upon his dogs, but he could not believe that the animal would venture from such a height into the midst of a crowd of men and women. Yet within ten minutes the leopard did venture, creeping down, making a dash among the startled company, and getting away safely with one of the terriers in its mouth.

Leopards vary considerably in size and weight, from specimens which may measure eight feet, down to the smallest, measuring only five feet from muzzle to tip of tail. The habits of all are very similar; they differ chiefly in the size of game they attack. Many people in African settlements fear this animal as much as the lion. Its ubiquity, its silent stealth, its daring, and its all-consuming appetite make it a much-dreaded foe. Between the true leopards and the jaguar comes the snow leopard, a smaller and slimmer animal than its American cousin, mainly inhabiting the high-lying lands of Central Asia. Here, in summer, it is said to ascend to a height of over 18,000 feet, and never to come lower than half that level, except in the Gilgit district of the northwest Himalayas, where it is reported to be found in winter as low down as 6,000 feet. Although captive snow leopards are not uncommon, our knowledge of the species wild is limited.

We know, however, much more about the jaguar, the king of the New World cats. The natural history of this splendid beast of prey has been carefully worked out. Exceptionally large specimens may reach a length of eight feet, or even more, but the average is considerably smaller. The jaguar is built on sturdier lines than the leopard, with enormously powerful limbs and paws. His home is in the semi-tropical forests of America, but he ranges far afield, as stockraisers are only too well aware.

THE TIGER, INDIA'S KING OF BEASTS

The tiger is preëminently the animal of India, where he levies heavy toll on human life, and many a village there has been depopulated by him. But it is in Siberia that he attains his greatest size, strength and luxuriance of coat.

A superb swimmer and climber, he is called a "water cat of arboreal habits." His prey are the tapir, peccary, deer, anteater, agouti, birds, monkeys, fishes, and even young alligators. In addition, he levies toll from herd and flock and is greatly dreaded as a man-slayer, the more deadly because he can lie perfectly concealed in a tree, to drop down upon the head of a man passing below. He will do battle with any animal he meets. He can kill an ox and drag it into cover; he can kill a horse.

Zoölogists sometimes, indeed, think the disappearance of the prehistoric horse from the American continent may have been due to the jaguars and pumas.

THE SAVAGE LYNX

The lynxes are widely distributed over the Old World and the New. Wherever found they are savage, rapacious animals, killing birds, hares, sheep, and other animals larger than themselves.

The jaguar resembles the leopard in its spots, and is called the American tiger. The puma, which is unspotted, is called the American lion or panther. This animal is a terrible scourge where horses, sheep,

Courtesy N. Y. Zoological Society

THE JAGUAR, WHICH CLIMBS AND SWIMS

The jaguar, which is practically as formidable in strength and ferocity as the lion or the tiger, has an advantage over both in that it is a superb tree-climber, as well as a notable swimmer.

and cattle are bred, and at one time the herds of semi-wild horses of Patagonia dwindled away before this lithe beast.

The puma is inferior only to the big jaguar in size, and is just as magnificent a climber; and the fact that it makes many a meal of the active American monkeys is sufficient evidence of its prowess. It is simply omnivorous in its tastes, and will eat anything, from a pig to a porcupine, from a horse to a snail. The most interesting thing about the puma is the fact that it will not, unprovoked, attack man.

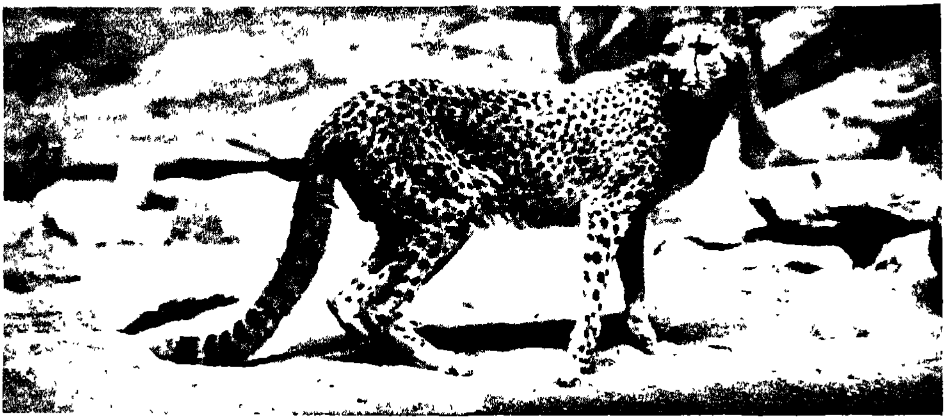
The last of the great cats is the clouded leopard, an animal restricted to life in the trees, where it lives on birds and small animals. Inasmuch as this beast may measure as much as six feet, there is reason to be thankful that it confines its operations to life above the ground. As a terrestrial animal it would add another terror to the natives of southeastern Asia, where it lives.

Other members of the cat tribe that hunt and fish

There are many other members of the cat tribe among the wild hunters of the world. There is the golden cat of the Indo-Malay area, which has a gray Chinese representative; there is the fishing cat, which not only eats the molluscs of Indian and Chinese swamps, but will eat sheep, dogs, calves, and even young children left unguarded. It is but little larger than the domesticated cat, but seems to have the ferocity of the genus in concentrated form. The leopard-cat, the servals, the tiger-cats, the eyra — which is the weasel of the cat tribe — the Egyptian or Kaffir cat, from which it is believed the domesticated cats of Europe originated — these and others bring up the rear of the hunting cats, in which are also included, of course, the wild cats proper, some of which still survive in the more remote deer-forests of Scotland. The family tree closes with the lynxes, a widely distributed group, found in Europe, Africa, Asia, and America. Its habits vary with the locality. In North America it is an expert tree-climber; in Tibet it is quite at home in barren country among rocks and open ground. But wherever the animal may be found its nature is the same; it is sullen, ferocious, rapacious, with a delight in slaughter far beyond its needs.

The cheetah, or hunting leopard, is included among the leopards by some zoologists. But it is not a leopard. The highest opinion refers the animal neither to the cat tribe nor the dog tribe, but to a genus of its own. The important difference first noticed is that the cheetah cannot draw its claws back into their sheaths, as all true cats can; they remain partly protruded, more after the fashion of the claws of a dog. There are important features in regard to the teeth, and the singular slimness of the body and its immense length of limb give the animal an unmistakable outline. It is common to Africa and India, but in India it is famous as a courser and hunter.

The buck is thrown and pinned by the throat. It is said that for two or three hundred yards the cheetah can travel at the rate of a mile a minute. Should he not catch his quarry within 500 yards, however, he gives up the chase, lies down, and waits for the cart to come along and carry him. If the buck has been brought down, the huntsmen rapidly approach, draw a ladleful of blood from the victim, and offer it to the cheetah, which is still holding on to the deer's throat. The beast at once relinquishes his grip to drink the blood, and while he is thus engaged the hood is slipped over his head, and he has to wait until evening for his meal of flesh from the animal he has killed.



Courtesy N. Y. Zoological Society

THE CHEETAH, WHICH IS USED BY INDIAN PRINCES FOR HUNTING

It is caught when young, and trained to pursue and kill game by Indian princes who keep cheetahs for this purpose as we keep dogs and hounds. No cheetah bred in captivity, it is said, can ever be made into a successful courser, and the captive is not considered perfect until full grown. When he is to hunt, the cheetah is carried, hooded, upon an open cart to a spot where game is to be found. As soon as a buck is sighted, the hood is withdrawn from the cheetah's head. In a moment he sights the game, drops down from the cart, and begins to stalk low and creeping, as a cat stalks. When the quarry gets on the move, however, the cheetah flings caution to the winds, and launches himself like an arrow in pursuit.

The wild cheetah is very tenacious of life, and one has been known to charge at astounding speed for 140 yards with a heavy bullet clean through his heart. This, however, is characteristic of all the great cats. Lion, tiger and leopard will charge again and again with limbs smashed, riddled with bullets. Hagenbeck once had two snow leopards both of which lacked a hind foot, torn off in some trap. But in spite of their sufferings the animals survived and bred. The great carnivores, in the natural state, stand misusage almost as well as reptiles, and are as hard to kill, which brings us back to the thought with which we opened this chapter — the wonder that man should ever have survived his early combats with such terrible rivals.

THE VEDDAHS OF CEYLON, PROBABLY THE MOST PRIMITIVE PEOPLE NOW LIVING IN THE WORLD

The Veddahs of Ceylon, generally regarded as the most primitive tribe in the world, represent the lowest stage in human development. It is believed that they descend from the original inhabitants of Ceylon, where they now live in a territory by themselves, preserving habits and customs unchanged for 2000 years.

From a photograph by Skeen & Co., Colombo

THE PRIMITIVE PEOPLES

Qualities of the Lower Races of Mankind, and the Invasion of Their Territories by Civilization

TYPES OF MAN DOOMED TO DISAPPEAR

WE have gone so far as to assume, with all modern authorities, that the human race had but a single origin, and from the evidence at hand, we have found reason to place the site of the origin in Asia. It is supposed the first creature that could be called man arose there, and began to spread in all directions, impelled by hunger, curiosity, love of adventure — those same motives which urge the pioneer and the traveler today. But wherever he went he remained a single species, the human species, and to this, in a generous spirit, systematists have given the name of *Homo sapiens* — man the wise.

We shall suppose, then, that all the human beings now upon the earth own a single ancestry, and that they all belong to a single species, *Homo sapiens*, so that, however various its members may be, they are all human, and can all produce offspring with one another — as readily, it would appear, with extreme intermixture of race as with none. This, we may remember, is one of the classical tests of what is usually understood by a "species," and as far as the test has been applied, all *existing* men belong to one species.

We have, of course, some speculative titles to apply to definite human forms in the past, and may give them names which assume that sapience or wisdom is only a modern product. Thus, we may speak of *Homo neanderthalensis*, represented by the famous Neanderthal skull, or of *Homo primigenius*, primitive man, or of a supposed *Homo alalus*, or man before speech. But whatever these names and speculations may lead to, they do not help us much as regards existing man, who is now our problem.

He is found all over the world: in the tropic zone which supposedly bore his first parents, and in the temperate and polar regions. He presents an enormous variety of physical and social form as well as culture. The mighty fact called society, and the social heritage, rich or poor, which is transmitted from generation to generation, outside the realm of the "germ-plasm," complicates incalculably the problem of the anthropologist. If there were no such thing, and he had simply to deal with creatures like animals, which are in practically no degree social products, then he could confidently assign their natural rank to the various kinds of men whom he surveys. But that is not the problem before him. He has to reckon with culture and education, and tradition, and institutions; he cannot instantly determine, on mere inspection, whether an apparent barbarian may not be simply a "diamond in the rough" and he may be constantly mistaken in individuals, well dressed, fair spoken, and elegantly groomed, who turn out to be little more than veneered savages.

Needless to say, there is a slap-dash method of judgment, mainly depending on skin-color, which wastes no time with these refinements. If we know what we — or, rather, the race-prejudice of which we are the slaves — want to believe, our difficulties are at an end. Anyone who is not just like us is a "native" or a "foreigner"; anyone whose skin is more highly pigmented than our own is "not of our type"; any language we do not understand is a "jargon." To the shaven Greeks all other peoples were the "bearded" (*barbaroi*).

The differences of race which go far to explain race-prejudice

Even to some of us today anyone who is not exactly of our manner of dress is still a barbarian, and all men whose civilization is not modern are savages. But the time for all that is past. Science, which ceases to be science the instant it entertains a prejudice, has to study these facts impartially as it studies the varieties of atoms; and its verdicts are frequently in direct opposition to what prejudice or even mere casual inquiry suggests.

So far, indeed, has the pendulum swung since the old days that a new prejudice has to be faced by science. As recently as the year 1911 there was held in London a Universal Races Congress, in which this new prejudice had a liberal hearing, if, indeed, it did not drown the voice of science. It is to be spoken of with the utmost respect, for it is humane and generous, but it is vain. Whereas, on the one hand, men err profoundly when they seek to dismiss as inferior all forms of civilization or society which are different from or simpler than their own, yet, on the other hand, the view cannot be maintained that, if only we would allow for differences of culture and opportunity, all races are equal. It is not so. Race is a fact, and the differences between races are facts. These differences, unlike beauty, are more than skin deep. They extend into the realm of nerve and mind, and involve superiority here and inferiority there.

If this be a fact of science it must be accepted, as all such facts must. It goes far to explain race-prejudice, but it offers no justification for race-prejudice. It goes far to explain the conflict between races and the horrible incidents of such conflict, but it offers no justification for the savage treatment of savages by civilized people. We must sharply distinguish, once and for all, between the scientific statement of facts and any judgment upon the moral questions which those facts are bound to raise. Science, perfectly indifferent to the color of the skin, examines the brain of the white man and of the black. It finds both brains white, as all brains are, and its impartial judgment is in favor of the white man's brain. Religion and ethics have to deal with the problems involved. They must neither bully science to deny what it knows, nor must they confound the verdict of science as to what *is* with the question of what *ought to be*.

Here we have referred to the races in question as "primitive" — a term which definitely suggests that they represent an earlier stage of human development than the races who do not come into this category. The term will probably remain in general use, and it is certainly a better term than "savages," but, as science is now beginning to discover, there are serious objections to it.

In the first place, it is quite certain that no existing races are primitive in the sense that they represent primitive man. Of that we may be perfectly confident. Primitive man, and many stages of development later than his, have gone forever. We need not turn to the lowest of existing races in the hope that we shall find primitive man before our eyes.

The mistaken impressions of the missionaries about the lower races

In the second place, there is a fact called degeneration, which is probably as common as any of the major facts of human history. In olden days missionaries always assumed degeneration in religious belief. Missionaries were largely the pioneer anthropologists, and we need not despise their efforts. When they found rude peoples who believed in many deities, and whose religion was to be called polytheism, missionaries assumed that this was a degeneration from an aboriginal monotheism. That view cannot now be held with absolute certainty for the evidence at hand indicates that polytheism represents an earlier stage of religious belief. However, we are not at all so certain that the missionaries were entirely wrong. In various parts of the world, often in circumstances of more or less physical isolation from the rest of mankind, as in Papua or Ceylon or Tierra del Fuego, we find human beings who seem ruder and lower than any others, and we commonly label them "primitive."

LIFE PICTURES OF PRIMITIVE PEOPLES

A GROUP OF KAFFIR WOMEN SITTING WITH THEIR CHILDREN

© Underwood N Y

THE AINOS OF JAPAN

The most primitive native race of which any trace can be found in the island empire of the East

PEOPLE WHO LIVE IN TREES

The natives of New Guinea shown in this photograph still build their houses in trees

KAFFIR CHILDREN AT THE DOOR OF THEIR MUD HOUSE

The pictures on this page show types of three primitive peoples, but it should be remembered that no existing races are primitive in the sense that they represent primitive man Nor are such races necessarily degenerate We mean by primitive races people displaying primitive forms of civilization and of culture. The upper and lower pictures of Kaffirs are from Kidd's *Savage Childhood.*

The real character of men living apart from civilization

Usually they are living in conditions of extreme difficulty, near to starvation, much exposed to an inclement climate, and unable to do any better for themselves.

In such circumstances reason and analogy would suggest that we are dealing, not with a primitive people, but a degenerate people, and that we must therefore be wary of drawing conclusions from their condition, which may tell us no more of the real truth than would an examination with similar assumptions of the slum population of one of our great cities.

In the world of life, descent is at least as easy as ascent; nay, it is far easier. When human beings live in dark forests, on barren island shores, on sterile soils, near the poles, or otherwise under physical conditions of extreme difficulty, they are no less liable to degenerate than are beings of any other living species in parallel circumstances. Races of these kinds can be studied with interest and profit, so long as any of them remain, but we should not call them primitive. They have gone back to nature, but they have gone too far.

The truth is that Rousseau and his followers, entirely destitute of any anthropological knowledge, have too long misled modern men as to the character of those who live apart from any form of civilization, with what that demands and what it supplies. The "noble savage" who throve in a state of nature before man invented civilization and "spoilt everything" — this delightful being never existed. The argument of Rousseau and his school that "all civilization is a state of social degradation," and that "the primeval savage life is the state of human simplicity and perfection," is as gross and ludicrous a perversion of the truth as ever a clever man deceived himself, as well as others, with. When we study existing men who live under the conditions which Rousseau desired, having no property, no laws, no government, none of the social inequality which he, very rightly, no doubt, denounced, the last thing we find therewith is human happiness and dignity.

The sad life of the superstitious and degraded man of a savage race

If natural man has favorable enough conditions, he multiplies, and his multiplication makes civilization of some sort necessary. If he tries to face nature in his natural state, his nakedness and weakness of body being thus unaided by his mind, his life is not worth living. As a modern writer has forcibly put it, mankind can no more go back to nature now than any one of us can return to his mother's womb.

These savages, as we may justly call them, provided we do not refer to their temper — for they are not savage in disposition — are literally degraded, and drag on an existence which is scarcely to be called human. They are commonly undersized and emaciated. Their minds seem full of superstitious fears and horrors. Their incessant problem is how to live and find shelter. They are the prey of innumerable parasites, and become senile in their thirties; and they represent the quality of mankind in its naked state of mind and of body, for they have no social heritage, and thus nothing but the merely physical to transmit to their offspring. Before we condemn and despise them, we have to decide exactly what we ourselves would have amounted to had we been born and reared under such conditions of physical hardship, and without the vestige of a culture to assimilate. "Self-made" men, in a stricter than the usual sense, what reason should we have had to take pride in our achievement? A "self-made" man sometimes looks the part.

The races of men who must be studied quickly before they disappear

But above and apart from these races of more or less degraded savages, we find other peoples, in almost all parts of the world, such as the Maoris and the Zulus, who are still very remote from ourselves, but who cannot possibly be ranked anywhere near such indigenous races as the Veddahs of Ceylon, or the Ainos of Japan.

If the word "primitive" is to be used at all, it should be applied to such races as those to whom we are now referring.

They show no signs of degeneracy — until we begin to civilize them, that is to say — and though they are æons apart from "primitive man," they do display primitive forms of civilization, and of culture. Our contact with them modifies their culture, and involves their slow, or even rapid, extermination. They must therefore be studied quickly, or not at all; and this study must include both physical anthropology — which is, indeed, of lesser interest — and the study of their minds and beliefs and customs.

The physical anthropology of such races need not long detain us. The general conclusions to be drawn from it are definite enough The main facts of anatomy and physiology, thus compared in different races of men, entirely justify the belief that all human beings now extant, whatever may be the case as regards extinct forms of man, belong to one species. Nevertheless, differences in skull-form and so forth are certainly to be found; and in these respects the advantage lies with what we call the "great" races, though their inherent and natural advantage is much less than we are too commonly inclined to suppose.

The effect of climate and environment on the characteristics of races

The recent work of Professor Franz Boas in the United States must also be noted in this connection, for his study of the children of immigrants of various races suggests that climate and natural environment modify racial characteristics as few had hitherto supposed, even to the extent of radically altering the proportions of the skull, which anthropologists have for so long been disposed to regard as immutable throughout the ages.

As regards skin-color, so superficial, and therefore so conspicuous and notable, and therefore also so insignificant, the modern evidence suggests that this race-character is profoundly modifiable by environment or, to be more precise, by the quality and quantity of sunlight. The late Charles E. Woodruff, an ethnologist, went far to show that skin pigmentation is protective, guarding the blood and deeper tissues from the powerful action of the "chemical rays" in the sunlight. This pigmentation becomes very marked even in the skin of the white man when he is exposed to the tropical sun, and it must be remembered that the white man is only relatively white, having pigment and pigment cells in his skin, and being quite distinct from the really white man, who is abnormal, and termed an "albino"

The study of the mind of the primitive races

Professor Karl Pearson has advanced the theory that the white races are an albino "sport" derived from the black, but this view has not found favor with any first-hand students of man.

When we turn from the physique to the *psyche* or mind of the so-called "primitive" races, we find a field of the deepest interest and instructiveness, which would well accommodate a thousand times the present number of workers. Here the missionaries of the past have taught us much, and modern missionaries teach us more. The cause of pure science and human progress would greatly benefit if all who went as missionaries to the "heathen" could first receive at least a year's training in anthropology and in the methods and pitfalls in the observation of such peoples.

An important fact should be noted in dealing with the individual psychology of primitive peoples, which has led to much erroneous belief. It is more important than anything we can learn about their bodies, and it must be understood if we are rightly to interpret their societies.

The degeneration of the Kaffir boy as he grows up to manhood

Observers have constantly reported that the children of lowly races, such as the aboriginal Australian, the now-extinct Tasmanian, or the rapidly multiplying Kaffir, compare favorably on all counts with European children. The view that such races are mentally inferior has been challenged on the evidence supplied by, say, competitive examinations for ten-year-olds of white and native races.

The native children are just as intelligent as the white, just as charming and curious, interested, lively and lovable.

The same cannot be said, however, of the adult Kaffir as of the Kaffir child. Indeed, as Dudley Kidd and other first-hand students have taught us, the children of these lower races *degenerate* at puberty. The boys especially, when they become men, degenerate mentally; and their whole being and interests seem to be thereafter almost wholly confined to the channel of sex. This degeneration is much less marked in the women. In consequence of it, the native child may be the equal or the superior of the white child, but the native adult is inferior.

These observations raise matters which concern us all throughout our lives, as individuals, as parents, and as citizens. Here, however, they are to be looked at simply from the standpoint of the comparative study of man. Observations show that adult man everywhere is a developed form of the boy, physically speaking, as the growth of his beard, the changes in his voice, the development of his skull, and other characteristics testify. In all races this development in bodily structure may be accompanied by psychical degeneration, due perhaps to lack of development of certain inhibitory functions.

The boys of the lower races who are brighter and better than the men

It is not only among Kaffirs or among the native Australians, unfortunately, that the boy is nicer, brighter, more original, more sympathetic, more interested, less selfish, more generous, quicker in memory and invention than the man; and it is the emergence of sex in both cases that makes the turning-point. In the lower races, sex would appear to be scarcely transmutable by self-control into higher forms of activity; hence the difference. The constant disappointment of missionaries and educators is thus explained.

If now we turn to estimate these lower peoples from the standpoint of their culture, we find occasion to revise almost wholly the older estimates. The student of our culture — apart from buildings and automobiles, etc. — would require to live with us and gain our friendship, or, at least, lack of suspicion and hostility, before his observations could hope to go very far. Similarly, what we see in casual observation of primitive peoples on whom we have forced ourselves is a mere nothing. Prolonged inquiry under conditions which make any inquiry profitable reveals the fact that these supposed savages have a civilization or culture of their own, which is worthy of study, and often of our profound respect.

Clear perception of essentials in social institutions among many primitive races

For instance, on the mere score of complexity and complete working out of detail, the marriage system of the primitive Australians surpasses anything we can compare with it. It has taken decades of study for us to gain any knowledge of it, much more to understand its meaning and origin. But there it is, with its recognition of relationships between individuals, and of duties of *taboos*, privileges, and restrictions, so subtle and detailed and rigorous that our social system is a chaos by comparison. Ours may be better for us, but the present point is that we cannot apply the name of "savages" to people who have developed such social institutions as Australian marriage.

In certain fundamentals we still have everything to learn from primitive peoples. Though they are by no means living next to nature, as are the rude races whom we have already discussed, yet they are in many ways nearer to the perception of essentials than we can readily be. Thus in such matters as the protection of girlhood and boyhood, of womanhood and motherhood, many primitive peoples have for ages practiced what our most advanced reformers are still hoping to see the dawn of among ourselves. The Maoris or the Bantu know nothing of the neglect of youth which is part of our social practice. The Zulu mother is protected; the unmarried expectant mother is given to the charge of a young warrior, and the guilty father is assegaied. No woman, young or old, is unprotected.

A very natural and human question presents itself to the inquirer, and with it we must conclude our survey of these people. What is their future?

The answer must be, "It all depends." If they are brought into competition with Maxim guns and repeating rifles, merely "savage" weapons such as spears are wholly out-savaged. If the competition be of a subtler form, the primitive peoples still go under. Our diseases, and our ardent spirits, are too much for them. Very often they are killed by kindness — even the missionary who persuades them to wear European clothes may hasten their end. The Bible does not go to them alone, and they have no chance against our rum and our bacteria. In the case of the Tasmanians, it looked as if removal from their native island, and nothing else, prevented the race from continuing.

Certain African races good examples of the multiplication of primitive types

But there are no inherent reasons why these races should disappear. Certain primitive Africans, under favorable conditions, have multiplied to many millions in the New World, where not a single negro existed until the white man imported them. There are some twelve millions of human beings whom man has simply *made* there. Though the death-rate is high from narcotics and tuberculosis, the birth-rate is also very high. In general, we see that the survival of these lower races in the future entirely depends on the conditions to which they are exposed. Now that they are not simply to be shot down, they may multiply as never before, and where never before; or they may disappear.

The very lowest existing types of man are doomed. Many scanty tribes, here and there, each with its lesson, cannot long survive their discovery by civilized peoples. But the African native, especially furnishing a very fair sample of a primitive people, is certain to constitute one of the great world-problems for many generations to come. The verdict of anatomy and psychology in this case is perfectly clear.

The verdict is that the negro does belong to an inferior race. His brain capacity is poorer, its construction simpler. His psychological type, *on the average*, is lower, most notably in the matters of judgment and inhibition, or self-control. It is in this respect that alcohol, and other drugs which paralyze self-control, are his enemies.

If the anthropologist could report otherwise, no doubt he would. His study of mankind, and his interest in human types, tend toward humanity and sympathy with those whom he studies; and he has no desire to report anything which would lead to other feelings. But the interests of scientific truth are paramount, not merely because truth is truth, but because we must know in order to control, and because false hopes are not worth fostering. Impartial students in the United States report very unfavorably on the influence of the race of lower psychological type upon the less controlled members of what is really the higher race. Many of the least pleasing features of American civilization seem to be due to this vitiating factor.

Union of the higher and lower racial types a great problem of the future

On purely biological grounds, the intermarriage of higher and lower races is more than dubious: it is to be condemned, at any rate, as a general social practice. The intermarriage of races has never yet been clearly analyzed according to the totally distinct groups, in one of which the intermarrying races are equal, and in the other of which one is inferior. The most sympathetic anthropologist, who knows the best as well as the worst of the primitive peoples, who would greatly regret their disappearance, and who desires to see the utmost possible made of them, is left no choice by the canons and conclusions of his science but to deplore the union of higher and lower racial types.

That, however, will increasingly be the problem which the future has to face, and the survival of lower types of man depends upon how they respond mentally and physically as they come in contact with the higher types of man, the perfectors of our modern world.

WHERE THE MILLIONS ENJOY FRESH AIR AND GOLDEN SUNSHINE

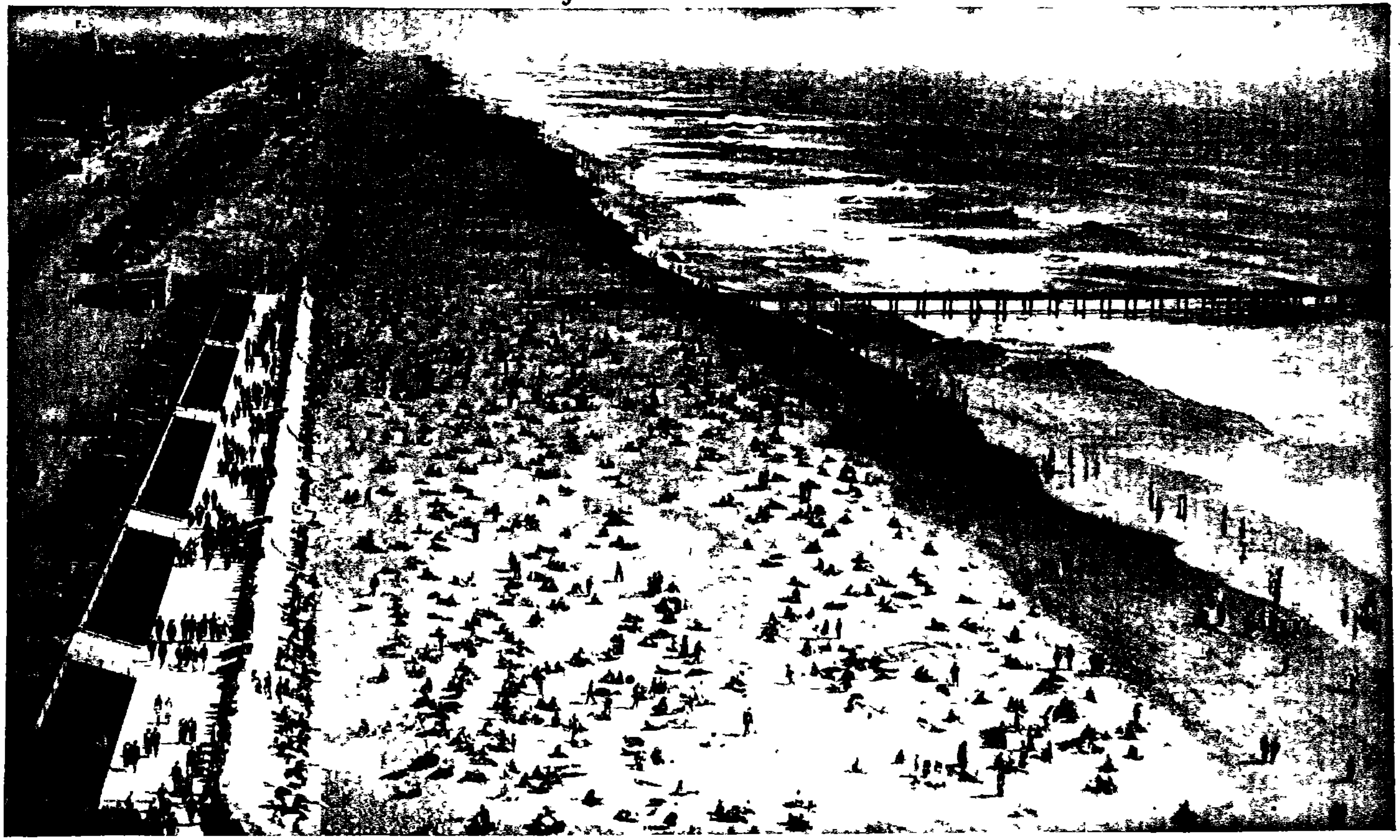


Photo from Ewing Galloway, N. Y.

OCEAN BEACH AND ESPLANADE NEAR GOLDEN GATE, SAN FRANCISCO, ON A SUNDAY AFTERNOON

A CEASELESS FLOW OF AIR

The Natural Enemy of Ill-health Which Is within Reach of Every Home in the World

THE OPEN DOOR AND THE OPEN WINDOW

THOUGH so much nonsense has been talked about "change of air," which usually means change of everything but air, there is no doubt that unless we have *incessant change* of air, we die, and that is why we breathe.

We breathe in for one purpose, and out for another, the two being totally distinct. We breathe in so as to help ourselves to oxygen, and for no other purpose. If that were the whole of breathing, there would be little difficulty, for there is plenty of oxygen in the air, and we need not fear to exhaust it. The real problems for health begin with the breathing out. It is what cometh out of a man that defileth. We expire or breathe out in order to get rid of poisonous products of our own lives; and if we fail to do this successfully, we expire in another sense

Experiment shows that we can do without oxygen for a considerable period, provided that we be allowed to get rid of *our respiratory poisons* The symptoms of suffocation or asphyxia are symptoms not of starvation, but of intoxication. Thus, when we inhale "laughing-gas," which prevents the blood from carrying its oxygen, we do not die, nor are we in danger at all of death, for the "laughing-gas" does not interfere at all with our getting rid of our poisons. If it did that, we should die at once, but it only deprives us of oxygen for a little, and so we merely lose consciousness.

This argument is of vital importance as regards ventilation and breathing, and as regards food and exercise and cleanliness. In these and all other cases it may be asserted that the usual risk is that of poisoning.

Now the human body can stand much deprivation of all kinds, some deprivation of air, and great deprivation of food, exercise, and light, but it quickly succumbs to *poisoning* Life has its reserves for emergencies, but if it be not allowed to rid itself of its waste products it is quickly choked, and dies.

When a room becomes stuffy, we suggest opening the window and letting in a little fresh air. Lack of fresh air is the cause of our discomfort and headache and drowsiness, we suppose. The fact is quite otherwise. We should speak of opening the window to let out a little foul air. So far as the oxygen need is concerned, we are no whit worse off in what we call stuffy air than in fresh air. There is a little less proportion of oxygen in it, but in any case there is more than we need, and our blood remains as fully saturated with oxygen in an unventilated room as in the open air. It is the products of our breathing that are present in the stuffy air, and cause our symptoms. They are not symptoms of starvation, but of poisoning. We prefer to speak of letting in the fresh air, for that sounds more elegant than letting out the foul air, but the question in these pages is not elegance, but truth; and truth says that we have been breathing over and over again the befouled air which our own lives have necessarily produced, and that we must get rid of it.

People who really understand this get to feel that sitting in an unventilated room, and much more sleeping in an unventilated bedroom, is *dirty*, just as not removing the sweat from one's skin or not attending to other bodily demands is dirty.

Japanese consider that to wash one's body in a bath, and then lie in the bath, is dirty. They prefer fresh water after washing themselves; indeed, they, and Eastern peoples in general, prefer running water in which to wash the outside of their bodies. Just so do wise people prefer running air in which to wash the insides of their bodies.

The difference between washing the inside of the body by expiration and washing the outside of the body by perspiration and the use of water is simply a matter of bodily convenience. The two processes are essentially the same, and some animals, and nearly all plants, use the whole surface of their bodies to breathe out by, though we use only our lung-surfaces, which are deep inside the body. From the point of view of health, expiration and perspiration are both simply forms of excretion, just as inspiration and eating and drinking are different forms of absorption.

How our personal habits affect the question of housing and sanitation

This argument helps us in the study of ventilation, because it prepares us to realize that the air in which we live is constantly being soiled, not only by what our lungs contribute to it, but also by what our skin contributes to it. Lungs and skin alike are getting rid of what the body does not want, and both are thus soiling and spoiling the air. Our clothes must necessarily be affected in the process, and soiled clothes substantially help to befoul the air. When one says soiled clothes, one is not thinking of mud or ink or paint or any such thing that has reached them from without, but the really objectionable dirt that has reached them from our perspiration. Numerous experiments seem to suggest that ventilation would be far less urgent a matter if people all kept their skins and their clothes scrupulously clean.

The greater part of the offensiveness and the injury to health which distinguish crowds of people, indoors and out of doors, in this part of the world would disappear if they were as clean, as regards skin and clothes, as the Japanese are.

A Japanese crowd is quite odorless, but the expired air of a Japanese crowd is exactly the same as that of a similar American crowd. The gases found in the air of an unventilated room will experimentally cause symptoms of faintness, headache, sickness, fatigue, and so forth. But if the experiments be made with the gases found in expired air — thus not including those produced by skin and clothes — these symptoms are much diminished, and indeed can often not be produced at all, so long as sufficient oxygen be supplied.

These more or less recent results of science are of much more than merely theoretical importance. They prove, to a degree never formerly suspected, that the problem of ventilation, of hygienic architecture and housing, is largely complicated with, and modified by, the problem of personal cleanliness. In short, ventilation is not merely a problem of air supply; it is scarcely less a problem of soap and water; and the air of a house is kept pure not only by the open window, but also by the bath, the tub, and the laundry.

However, we are not yet by any means ready to tackle this gigantic fundamental problem of ventilation, which sounds so simple, and is so often insoluble; but when we do come to it, whether on the printed page or in the railroad car or theater or bedroom, we must always realize, in future, that ordinary cleanliness is part of it, just as expiration is itself an act of cleanliness. We must realize that internal and external cleanliness are parts of one whole, and can never safely be divorced.

The importance of washing in flowing water and breathing in flowing air

Meanwhile, we have some more first principles awaiting our attention — though none of more importance than those which teach us that to enter, say, a second-rate vaudeville theater during an intermission is for all practical purposes, and on all scientific grounds, just as clean and pleasant an act as entering a bath in which half a dozen people have already washed themselves. Of the two, the bath, provided one kept one's mouth shut, would certainly be much less dangerous.

The dirt in the air of the crowded "movie" theater, air in which so many people have been washing the insides of their bodies and their skins and their clothes, can partly be filtered by one's nose, but much of it inevitably enters the body. This is not very pleasant reading; but half the duty of the teacher of health is to show people how disgusting — if they only knew — are many of the things they do, and then they would do them no more. We must disgust people about the composition of street dust, for instance, or they will continue to trail their skirts in it, and buy milk and meat that have been exposed to it.

The only kind of night air which is to be feared

And now for the next principle of health and breath, it being agreed that one should wash in flowing water and breathe in flowing air. We see that, in those parts of the world, at any rate, where there are no aërial insects outside to inoculate disease, we should open our bedroom window at night. Not to do so is to expose ourselves to the only kind of night air which is to be feared — that which we make ourselves in our own bedrooms. Our fathers and mothers used to shut their windows in order to keep out the dangerous night air; we are to open our windows in order to let it out. It matters less that windows should be shut so long as rooms are not inhabited, though doubtless they are better open. It is when we live in a room that the window requires to be open. The common practice is to "air the room" when no one is doing the air any harm, but to close the window when we enter the room and proceed to spoil its air. No one would really follow this absurd custom if the principles of the subject were understood. We do not run the water through the bath when it is not being used, but we should run it through the bath when it *is*.

By opening our windows we obtain air, and avoid the process of partial suffocation to which we should otherwise be subjected. But we are now beginning to discover that, though fresh air is a very good thing, it is by no means the same as open air.

Fresh air and open air by no means the same thing

At first one is apt to think that fresh air and open air are the same thing, but the two terms should never be used synonymously. Open air is doubtless fresh air, but fresh air is not always open air. Subway air is, on the whole, remarkably fresh, and it sustains life without substantial immediate injury even to those who breathe it all day. The air of a modern coal-mine is also wonderfully fresh, or that of a modern hospital, but none of these is open air.

This may sound like a mere quibble, but it is a very serious matter. The whole experience of recent years has taught us that the open air has virtues of its own which inclosed air, however rapidly it be changed, can never hope to possess. When people who remain ill in fresh air are made to live in the open air they often get well. When children who have pined and been put down for stupid in well-ventilated class-rooms are sent to an open-air school, they often become healthy and vigorous and attentive and intelligent There is something in the open air — what the French call the "full" air and the "great" air — which cannot be imitated under any artificial conditions whatever.

The fact must be stated, because it is so important for health, and because it is bound before long to influence our city-planning and our schools and our houses.

Some of the reasons wherein lies the marvelous difference

But it would take too long for us here to follow all the experiments and arguments by which it has been sought to explain wherein lies the difference between open air and mere fresh air. Here we can note only two or three points.

Life in the open air is superior to living in any inclosed space, however well ventilated, because any inclosed space is constantly apt to become an infected space. It is part of the inevitable nature of all living things to vitiate their surroundings; if they are to keep themselves pure, they have no choice in the matter.

The difference between fresh air in the house and the open air outside

Directly we encamp, whether in the virgin forest or in a house, we do a risky thing. Floor, walls, roof, furniture, carpet, hangings, all become possible and probable sites for harboring infectious organisms, which we ourselves, in our goings and comings, are certain to provide. At the very best, we can only hope to maintain, indoors, conditions practically as good as those out of doors by the incessant practice of cleanliness. To admit the open air is vastly important — indeed, it is essential; and if we do so freely enough we may boast we live in fresh air indeed. But the fact remains that the fresh air, however fast it flows, is flowing through and over all manner of surfaces which involve some measure of danger to health. Therefore, though the air be one and the same inside and outside, to live inside and to live outside are not practically the same thing.

In so far as this argument is sound, the moral of it simply reiterates the moral of our discussion of excretion by the lungs and by the skin. We must keep our homes, and our places of business and amusement — in short, everywhere that is not completely out of doors — cleaner than ever. Once more the problems of air and of ventilation are found to be all mixed up with the problems of cleanliness.

This point demands the most insistent and often-repeated statement. A park is presented to a city, and we use such phrases as "another lung for New York." Parks are splendid things, but they do no good as "lungs," except to the people who at any given moment are in them. The dirty houses, with closed or with open windows, which, perhaps, look upon the very park in question, are just as insanitary as ever they were.

There is a fallacy in the minds of the public and politicians and social reformers in this respect. Parks let us have by all means, and a garden, as large as you like, for everyone's house, but they will not save or prolong a single life if people do not *live in them.*

Grace Darling spent nearly two-thirds of her young life in the open sea air, which far surpasses that of any city park, but she spent the remaining third of her life in a tiny, unventilated bedroom, and she died of consumption. Just so are hundreds of thousands of people now dying in our cities, while our parks and open spaces can do no more for them than the glorious night air of the North Sea could do for Grace Darling when she was in her bedroom.

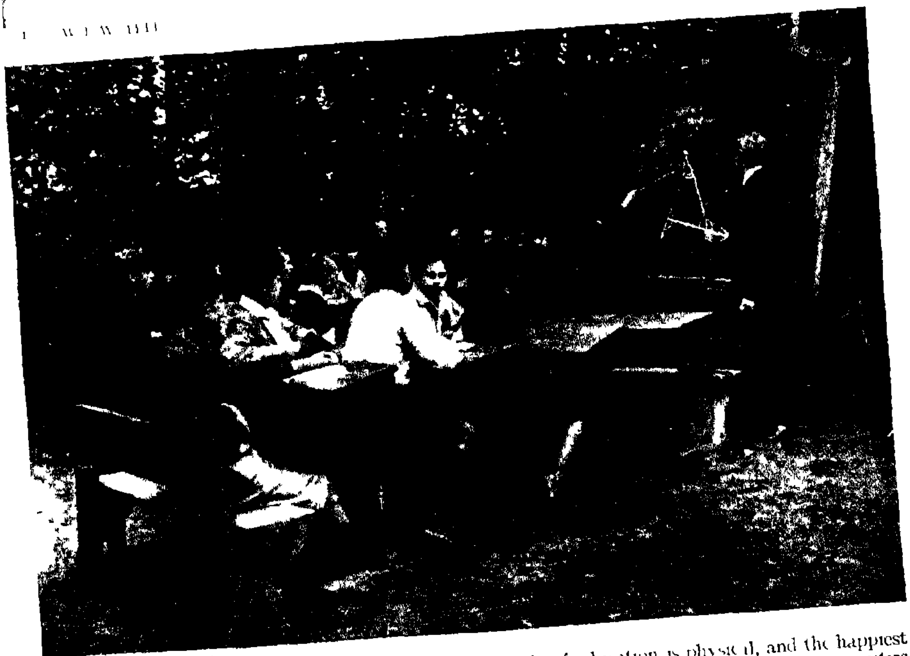
Now for the second reason why open air beats mere fresh air. It is simply that open air means, on the average, far more light than fresh air We know too little yet of the influence of light on human health and development. It is to be remembered that there is much more in light than meets the eye — rays invisible, but none the less potent.

How the sun, pouring in through the window, drives away the microbes

So obscure is this subject, and so very much neglected hitherto, that it is doubtful whether our knowledge of it would fill a single article of this section, though it is very likely that the real importance of it for health would entitle it to half a dozen. At any rate, what evidence we have suggests that the visible and invisible forms of solar radiation powerfully affect the body in many ways, and that their effects make for health, by their action on the skin, their absorption by the blood, and their stimulation of the eye, and through the eye, of respiration.

But even if the direct influence of light upon the body were nil, its influence upon health would remain incalculable, because of its destructive effect upon microbes. The germs of disease cannot face the light; and one of the greatest differences between living in inclosed air, however fresh, and living in the open air, is that the open air and the surface of the ground under it are so free from microbes, because of the antiseptic action of light. If this be added to the direct action of light on our bodies, the two facts, taken together, constitute an enormous hygienic advantage for life in the open air.

CHILDREN AT SCHOOL IN THE OPEN AIR



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More and more it is being recognized that half the battle of education is physical, and the happiest results have followed the experiments of open air schools in this country and abroad. In many cities the experiment has been tried with the greatest success. The difference between life indoors and out of doors is fundamental, and the best ventilated room built can never be quite so conducive to health as the open air itself.

The stimulating effect of a walk or a ride in the rushing wind

A third reason why open air is best is simply that it is much more in motion. We are apt to fear draughts, but few of us fear the motion of the open air. The breeze, the rushing wind, these not only make for health by their direct production of "change of air," blowing away our expired breath, but also by their stimulating effect upon the body. There is reason to believe that much of our health depends upon processes which are started through stimulation of the skin. All these new-fangled treatments by friction and massage and vibration, and also the fashionable bathing and rough toweling, owe their virtues in chief degree to their stimulation of the skin. Now, that is what the open air almost always does, except upon the very stillest day. It is, indeed, the second best stimulant in the world — second only to sunlight itself.

Its stimulant action is very readily seen when we find ourselves inclined to move about in the open air, as we generally do. It persuades us to take a brisk walk, or to run, or play. We thus are inveigled into taking exercise, and exercise combines with the stimulant action of sunlight upon our breathing to make that vital process deeper and more complete. A good run in the open for young people of either sex beats all the deep breathing exercises hollow.

Precious qualities of the open air which can never be reproduced indoors

The students of this subject are agreed, on all these grounds, that the open air is not only the best air, but that it is, and always will be, inevitably superior to anything else. Air may be filtered, moistened, scented, warmed or cooled, ozonized, electrified — what you will — and thereafter pumped, in the fullest quantities, into any kind of building. It will never rival the open air, and now we know why. It used to be said, before the days of exact and critical science, that the air lost some "vital principle" by such processes, and that because it was thus "devitalized" it proved inferior for life and health.

We now know that this is inaccurate. Air contains no "vital principle," in any sense of the words, except oxygen, and any air contains more than enough oxygen for the maintenance of life. The only occasion on which to speak accurately of air as "devitalized" would be when all the living microbes in it had been filtered away or killed. Such "devitalized air" would be the best for our vitality. But, as we have proved, it is profoundly true that no artificial processes can ever reproduce indoors, whether in a palace or a hovel, a scientific laboratory or an Eskimo hut, the qualities of the open air.

To the policy of the open window, which our age has lately adopted, there must therefore be added the policy of the open door. Man is the master of nature, but only on her terms. There are limits which we cannot transcend; and though we pretend to ourselves and each other that we can, nature is not mocked. The unique and irreproducible value of living in the open air is a case in point. No further advice need be given to the reader than to remind him, in the most pointed and personal manner, that a word to the wise is sufficient.

One of the many excellent points of the popular Boy Scout movement throughout the world is its encouragement to outdoor life among a class of growing boys and girls who otherwise might never have learned how to enjoy it.

The policy of the open door and the big window

It has to be admitted that we cannot possibly spend all our time out of doors, and that the hygienist must do his best in advising how most safely we may live indoors. His first duty is to insist on the policy of the open door, and protest that nothing else can take its place. Thereafter he must argue for the open window, of course, by night and by day, and for the making of windows as large as possible, in order that, whether they be open or shut, they may admit the light. Glass, by the way, absorbs certain rays of sunlight which are probably most valuable for health, so that the open air has the advantage again.

THE JOY OF THE OPEN AIR — FROM THE FINE PAINTING, "CUBBING WITH THE YORK AND AINSTIE," BY CHARLES FURSE, A R A

For the rest, we must do what we can in the way of ventilation Twenty years ago, the hygienist would have written with enthusiasm on this subject, the present writer did so himself Today one feels rather differently The textbooks are full of descriptions of the various modes of ventilation — natural ventilation, such as the open window, and artificial ventilation by the "vacuum" system, which sucks the foul air out, and the "plenum" system, which pumps the fresh air in. These questions concern us all from the point of view of public health and the proper construction of cities and buildings. They do not come into the present discussion, however, for here we are concerned only with personal hygiene, with our own health and conduct.

Most of us have to live where we can, and to enter what buildings we must, and the problem for us is to do the best we can in the circumstances. We have some control over the arrangement of our own homes, and for that we are responsible to ourselves and to those who depend or will depend upon us.

Why we should always open a window when we have a fire

The policy of the open window must be not merely preached or acquiesced in, but practised, by day and by night. Common sense suggests that we shall obtain more comfort if we open the window at the top. Some people like to open the lower sash, and insert an obstructive prop beneath it, so that the air can only enter in an upward direction, between the two sashes. This is not worth doing, for the air does not maintain its upward direction after entering the room. On no account will we ever close our chimneys, if we are lucky enough to have an open fireplace in any room, for they are most valuable adjuncts to ventilation. When the fire is burning it is reckoned that air passes up the chimney at the rate of about three feet per second, and this must, of course, be replaced in the room by the entry of fresh air from without. But even in summer the chimney is a valuable outlet shaft and should never be obstructed.

A fault in the factory laws that must be attended to

The mere size of a room is of little importance if there be no ventilation. There is all the difference in the world between cubic feet of space and cubic feet of air, though, unfortunately, the factory laws recognize the one but not the other. If the cubic feet of space do not have their content of air sufficiently rapidly replaced, one is no better off, after a short time, in a big room than in a small room. The largest bedrooms of a palace are not nearly large enough for the needs of a single sleeper throughout the night if the air be not changed.

This is a most important matter for the public health officer and the hygienic legislator, but it also concerns us here in one way. Though the size of rooms or public buildings constantly leads us to suppose that ventilation is less necessary, and though that is simply not the case, yet size has one advantage. It does at least mean that the necessary ventilation may occur with much less necessity for draughts. Obviously, to ventilate, say, a tunnel will involve more draught than to ventilate one's own bedroom, badly as that needs to be — and often is — ventilated. Therefore, while not relaxing the policy of the open window — it is better to be a "fresh-air fiend" than a "foul-air fiend" — one should try to keep one's rooms as large as possible, by an exceedingly simple device, which also greatly serves cleanliness, diminishes dust, and thus, in these ways also, serves the cause of pure air.

The folly of keeping air out of a house by useless furniture

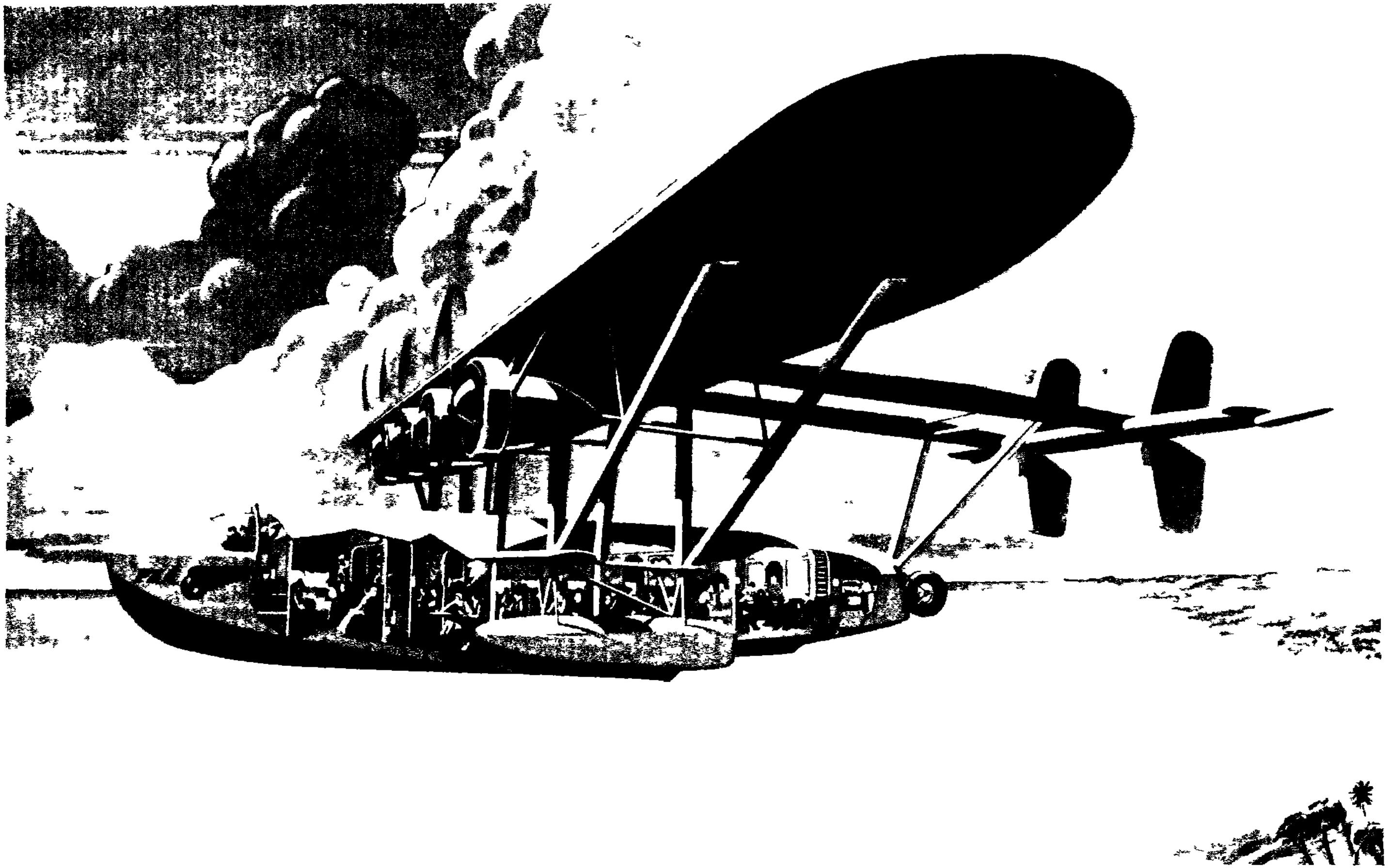
This device is simply the avoidance of all kinds of unnecessary and useless furniture. After all, there are many other ways in which one can demonstrate, or simulate, the possession of ample means, and this is a particularly foolish one. People who overload their rooms with furniture deliberately make their rooms smaller, for they necessarily reduce the capacity of the room.

We venture to say that those who have not made the measurements would be astonished to realize what proportion of the cubic capacity of an over-furnished or even a moderately furnished room is obliterated by furniture. The air that enters is necessarily restricted in its course. Add to this the effect of dust and dirt, and the number of dark places, and we can soon realize why unused "front parlors," and show-rooms in general, are so unpleasing to live in, when the rare attempt is made, and tend soon to become entirely useless — except as breeding-grounds for infection.

The good housewife is a great enemy of dirt and infection, and her passion for cleanliness is certainly a cardinal part of godliness, if by godliness we mean the religion of health and happiness and usefulness for self and others. But she is tempted, as we all are, to make a show, and here she defeats her own ends. She likes things sweet and clean and wholesome, and she hates dust and dirt. If she would only carry these principles out thoroughly, she would avoid a great many things which she prides herself upon — her unused show-room, her unnecessary furniture, her white curtains — which little dispose her toward open windows — and all manner of hangings and rugs and what not which make for darkness, collect dust, impede ventilation, and make her life a burden, besides keeping her far too much from pursuing the best policy of all from every point of view that matters in the long run.

That best policy is the policy of the open door. When all is said and done, and when we have made our homes as hygienic — and beautiful and distinguished — as we can, the open air remains unrivaled. We should learn to work in it, play in it, eat in it, be lazy in it, sleep in it, far more than we do. The veranda, the screened piazza, the sleeping porch, and the sun parlor, all so common nowadays in America, and which have done such wonders already, presage a revolution in our national practice, and the general adoption, not as a fad, but as common sense, of the policy of the open door.

AN AIRPLANE WHICH PROVIDES ALL THE COMFORTS OF A PULLMAN TRAIN



THE AËRIAL FLIGHT OF MAN

How He Can now Fly much more Swiftly than the Bird He Copied

THE WONDERFUL DEVELOPMENT OF AERONAUTICS

THERE is no branch of science which has shown a more remarkable growth during the past ten years than that which pertains to the navigation of the air. It is less than a generation since the first mechanical flight was made, yet, in that brief space of time, the airplane and dirigible balloon have come to be accepted as commonplace vehicles, having their place and their uses just as have the street railway and the automobile. Such feats as the transatlantic flights and the regular carriage of the mails by airplanes have been performed and are slipping back into the realm of the commonplace. As for the military uses of aircraft, the extension of combat to the air has almost revolutionized the practice of the art of war, and for a nation to undertake war without an extensive aerial equipment would be utter madness. The general who lacks air scouts is in the position of a man who attempts to play a game blindfolded against an opponent who suffers under no such handicap.

Various attempts to solve the problem of flight are recorded in mythology and in the history of the Middle Ages, perhaps the most important having been made by the Italian artist and scientist, Leonardo da Vinci. The most that any of these experimenters was able to accomplish, however, were short and unstable glides. The majority of them failed through a too slavish imitation of nature, the effort always being made to copy the wings of a bird. First among those whom we may declare to belong to the modern period of experimentation was an Englishman, Sir George Cayley.

In 1796 Cayley made a number of toy helicopters, or machines with directly lifting screws and no wings, and tested them with interesting results. The motive power was furnished by the elasticity of a bent piece of whalebone. As it was apparent that this did not furnish a satisfactory means of navigating the air, he turned to another method, and, more than a hundred years ago, produced a very accurate analysis of the forces which the wind exerts on a flat plate. He also showed the advantages of a curved wing section with a sharply dipping front edge. With this as a basis, he actually designed and built an airplane not very different, in its fundamental characteristics, from the machines in use today. We are told that this machine, when released at the top of a hill, would glide forward and land in the valley below, descending on a slope of about 8 degrees. Also, when a man ran forward on level ground carrying the machine with him, he would often be lifted into the air and soar for short distances. Cayley, however, like all the other early workers, was hampered in his tests by the lack of an engine. When Boulton and Watt brought out their steam engine he seized on it with avidity, believing that it offered the road to mechanical flight, and he has left calculations showing that such an engine would weigh 163 pounds per horse-power. Sir George never proceeded to the point of actually equipping an airplane with an engine. In addition to formulating the first principles of aërodynamics and investigating the steam engine, he prophesied the advent of the lighter internal combustion engine.

The very important experiments of Henson and Stringfellow

The next important experiments were made about 1840, by W. S. Henson, with the assistance of J. Stringfellow. Henson's specifications describe a monoplane equipped with a steam engine driving two screw propellers at the rear of the wings. The wings were to be braced in a manner practically identical with that still used on many large monoplanes. The machine was to run along the ground on three wheels while attaining its flying speed, and to have a rudder and elevator at the rear for control. The designs show a body of excellent form, which was to shelter the engine and passengers. In short, except for the power plane, Henson's airplane was thoroughly practical, and would not appear unduly freakish if placed beside a machine of the pattern of 1911 or 1912. The first tests were made on a small model which made successful flights, the power being furnished by a steel spring. A larger model, of 20-foot span, was then built and equipped with a steam engine, but the stability was not good, and the apparatus was prone to upset while running along the ground.

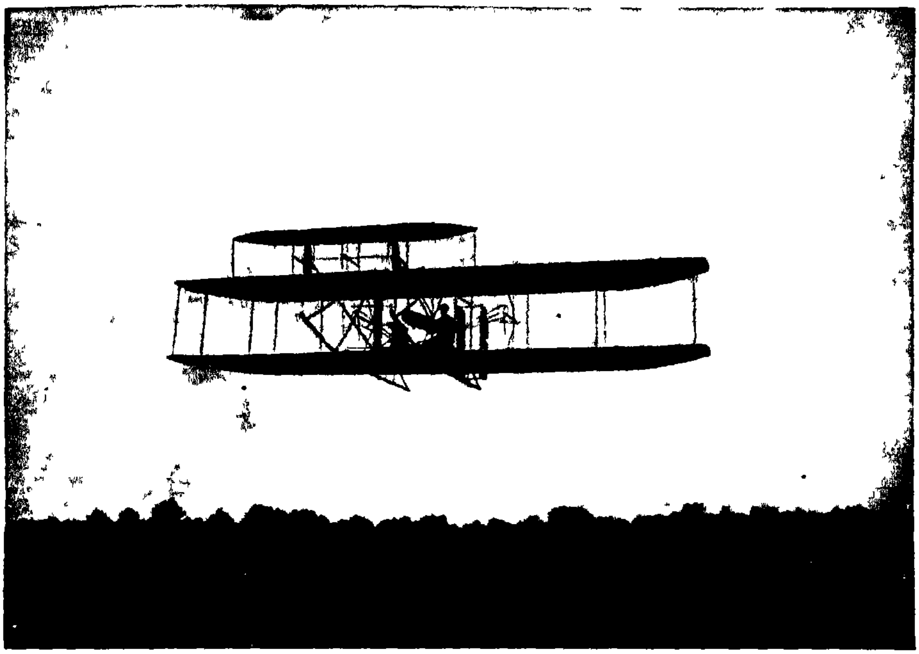
Stringfellow the first to build an operable engine-driven airplane

These experiments were performed, for the most part, in 1843. A few years thereafter Henson came to America, and Stringfellow continued the work alone. From 1846 to 1848 he was engaged in the construction of a small model of 10-foot span, much along the lines of those made by Henson, but with a better shaped wing, and weighing, complete with steam engine, about 8 pounds. This machine was tested in a large room in a disused factory, and actually made successful flights up to forty yards in length on several occasions, the length of flight being limited only by the size of the room. To Stringfellow, therefore, must go the credit of having been the first man in the world to build an operable engine-driven airplane. It is doubtful, however, that his experiments would have met with success had they been conducted outside in the open air where conditions are much more disturbed. After this achievement, he dropped the subject for some time, until he was attracted to it again by the formation of the Aeronautical Society of Great Britain and Ireland. Profiting by the work of Wenham (of whom we shall hear more later), he built a triplane which was exhibited at the Crystal Palace in 1868, and which was successful in lifting its own weight with an expenditure of about 1 horse-power.

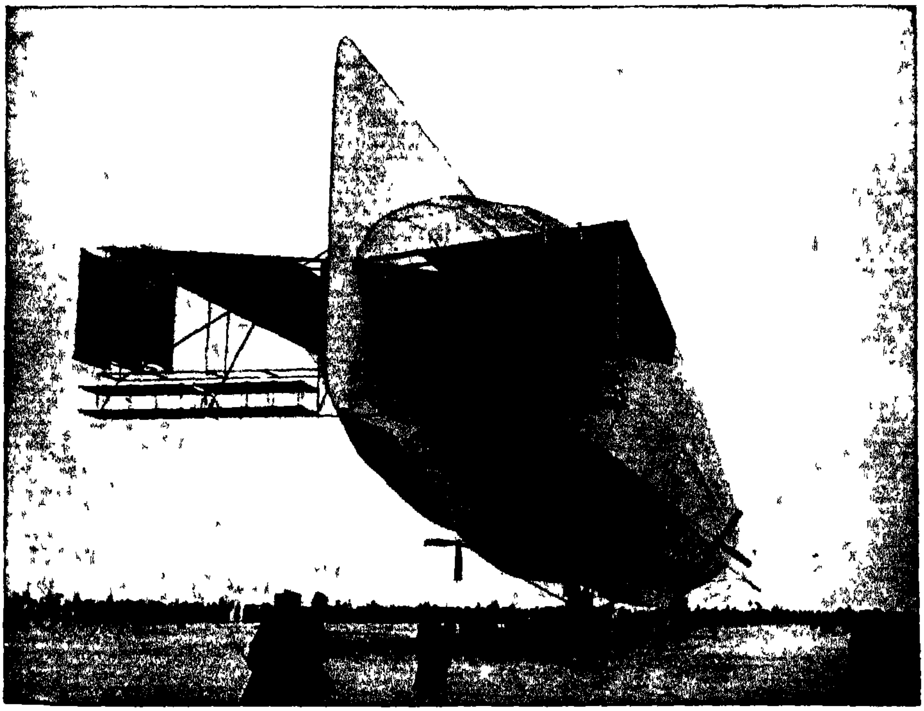
Wenham and the principle of "aspect ratio" of wings

Mr. F. H. Wenham first became interested in artificial flight as a result of studying birds. He made extensive investigations in bird-flight, determining the weight carried per square foot, the power exerted, etc., for numerous different species. As a result of his studies, he stated a principle which had not been fully appreciated until that time, although Henson and Stringfellow had made use of it in their machines: that is, that the ratio of length to breadth of a wing, or "aspect ratio," as it is now called, is of the very greatest importance, and that the longest and narrowest wings (length being measured crossways of the machine) always give the best results, other things being equal. Having decided on this, it was but a step to the design of a machine having a number of long and narrow surfaces arranged one above the other, thus gaining the advantage just spoken of without encountering the structural difficulties which forbid the building of a single wing of great span, yet of reasonable weight. Wenham's machines, however, had the surfaces merely attached at intervals to uprights which formed a part of the main framework. This prevented the shaping of the wing into a proper curve, and even made it impossible to keep it flat, as the air-pressure quickly distended and stretched the unsupported cloth. Mr. Wenham made various attempts at gliding, but never achieved much success, and his fame rests chiefly on his theories and studies, rather than on any practical construction work that he may have done.

THE MIDGETS AND MONSTERS OF THE AIR



THE FIRST MAN TO FLY IN EUROPE: WILBUR WRIGHT ON HIS BIPLANE AT PAU IN 1908



THE ENFORCED DESCENT IN FRANCE OF ZEPPELIN Z 4

All those so far mentioned were English, during the first half of the nineteenth century, the attention of French and other students of aëronautics being directed more particularly to ballooning. Now, however, the problem was near enough to solution to attract world-wide interest. The first notable French experimenters in aviation were Captain Le Bris and Louis Mouillard. They both built gliders, which they appear to have operated with at least as much success as anyone else had attained at that time, although the records, especially in the case of the first, are distressingly meager. Mouillard also wrote a most fascinating book, "*L'Empire de l'Air.*"

OTTO LILIENTHAL ON HIS GLIDER

In 1871 and 1872, A. Renaud made a number of models of various types, most of them driven by a twisted skein of rubber. He tried helicopters, similar to those of Sir George Cayley, wing-flapping machines, and airplanes with screw propellers. One of the latter made a flight of over 130 feet. About eight years later M. Victor Tatin built a larger model, employing a compressed-air engine and weighing nearly 4 pounds complete, which flew for about 50 feet.

We must now go back a few years to notice the work of Otto Lilienthal, in Germany. Lilienthal, like many others, began by studying bird-flight, but he soon saw what had escaped the others, that flying was a problem quite as much of operation as of construction, and that it would do no good to get a machine into the air in the hands of a man who had no experience in steering or balancing, and who would almost inevitably wreck it. He therefore started to secure the necessary practice by means of a glider. His first glider, a monoplane, was built in 1891 and enabled him to make flights of considerable length by jumping from the crest of a hill. All Lilienthal's machines had a tail, embodying vertical and horizontal surfaces, but it was necessary for the pilot to shift his weight by swinging his feet in order to prevent the glider from capsizing. Such a method of control was, of course, slow and tiresome and adapted only to very light machines. Lilienthal, in spite of this handicap, made nearly two thousand successful glides with both monoplanes and biplanes. He was just on the point of fitting an engine to his latest glider when he was killed, in August, 1896, due to the collapse of his apparatus. He had done very important work on the properties of arched wings, and had pointed out that the pressure on such a surface may actually be inclined forward of the perpendicular to the wing, contrary to the theories which had been generally held up to that time. Lilienthal recognized the defects of his system of balancing, and a letter which he wrote a few weeks before his death leads us to believe that he had then invented a much improved method, eliminating the shifting of weight, and was almost ready to try it.

From 1885 to 1895 Lawrence Hargrave, an Australian, and the inventor of the box kite, experimented with models driven by rubber and compressed air. He was particularly interested in the ornithopter, or wing-flapping machine, and one of his models of this type made a flight of over 350 feet. He became interested in other matters, however, and never attempted to build a man-carrying machine.

TRACTOR AIRPLANE AND LANDING FIELD

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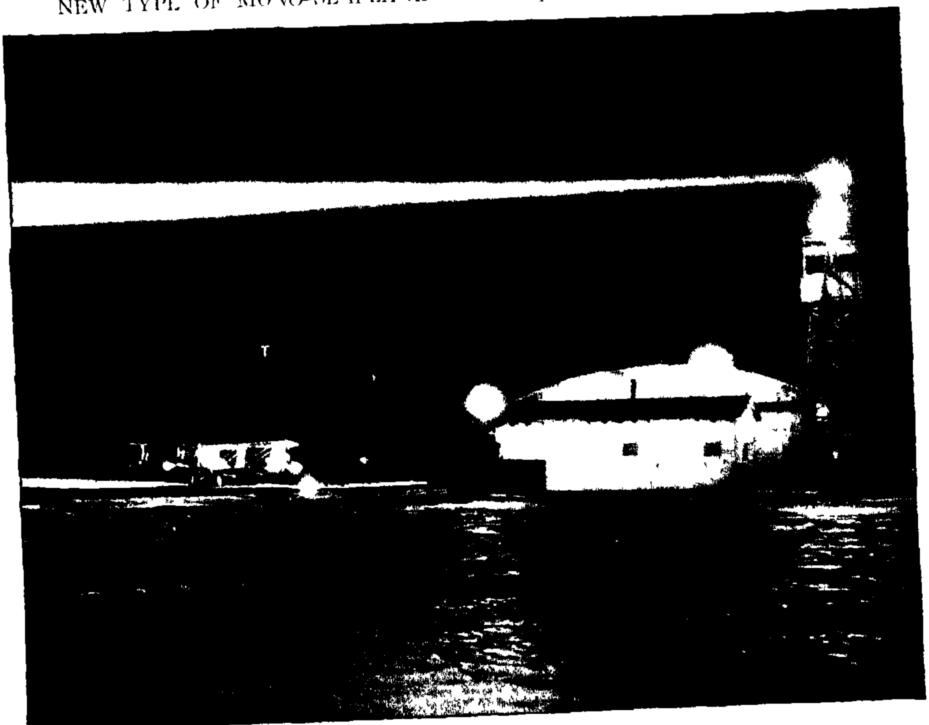
NEW TYPE OF MONO-SEAPLANE Note the pontoons for landing on the water



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AIR MAIL FIELD AT IOWA CITY This field is particularly well equipped with powerful beacon lights and signal towers to guide the aviators in their night flights

Following the experiments of Wenham, a young Englishman named Horatio Phillips, whose first machines were helicopters, later built an airplane which carried Wenham's idea of narrow superposed surfaces to an extreme. This machine had about twenty surfaces one above the other, each one being only a few inches in width, giving the whole machine somewhat the appearance of a Venetian blind with the slats turned horizontal. It was tested on a circular track, tethered to a post in the center, making, in 1893, unmanned flights of 1000 feet. A small steam engine was used. Phillips' most important contributions to aëronautical science were his studies on wings. The wing sections devised by him are very similar to some used today, and he forecasted their properties with remarkable accuracy.

Sir Hiram Maxim and his giant mechanical bird

Sir Hiram Maxim took up the study of mechanical flight purely as a scientific problem, and set out to formulate the fundamental principles with his usual patience and thoroughness. Having built a laboratory in which he determined the resistance of various objects in a moving current of air and their aërodynamical characteristics, and having made extensive studies on screw propellers and allied topics, he began the construction of a machine of vast size, weighing about 7000 pounds and having a steam engine which developed 359 horse-power. Maxim, realizing that he would not be able, without previous practice, to control so unwieldy a mechanical bird, provided overhead rails to prevent it from quitting the ground far enough to seriously injure itself or its passengers. During a trial run in 1893 the machine pressed so heavily against the rails that it broke away, and rearing up from the ground, toppled over and was badly damaged. Maxim had proved the possibility of dynamic flight with large weights, but his project was too ambitious for the state of the art, and served only to demonstrate anew that the mere ability to hop from the ground is of little value unless it is accompanied by proper means of control.

From 1895 to 1899 Mr. Percy Pilcher, a British marine engineer, built a number of gliders, the first being similar to those of Lilienthal, the later productions a decided improvement on those of the German. In most of his experiments he had the glider towed by a horse. Then, by measuring the pull in the tow-line, he could figure very accurately the power which would have been required to remain aloft. Like Lilienthal, he was just about to begin work on a power machine when he was killed by a fall, due to a structural failure of the glider.

The later story of aëronautics one of American achievement

Up to the present time, we have had little to say about the work of American inventors and scientists, but from the death of Pilcher until the day when the mastery of the air was actually accomplished, when a man first sailed forth from the ground in a long and perfectly controlled flight, the story of aëronautics is primarily a splendid story of American achievement.

Professor Samuel P. Langley, a physicist of world-wide fame and secretary of the Smithsonian Institution, began the systematic study of aëronautics shortly before 1890. Like Maxim, he endeavored to get back to first principles, and constructed a laboratory where many delicate tests were made. At this time, however, his researches were devoted to flat plates, and he rather neglected the great advantages of a curved wing. In 1896 his first large steam-driven model was completed and launched over the Potomac River. Its weight complete was 30 pounds, and it had 1 horse-power. This model, like practically all those which followed it, was a monoplane, but with two wings of equal size, one behind the other, and had two propellers behind the front wing. This plane rose from the roof of a house-boat and flew for about a minute and a half on several occasions. After experimenting with models for several years more, Professor Langley felt that the time was ripe for the construction of a man-carrying machine, and proceeded to design one.

Before the construction was complete, he built a model exactly one-quarter the size of the large airplane, and equipped it with a gasoline engine developing 3 horsepower. On August 8, 1903, this model made a successful flight from the roof of the houseboat, — the first flight ever made by a model equipped with an internal combustion engine such as Sir George Cayley had predicted ninety years previously. A month later the large machine was ready for trial, and an attempt was made to project it into the air with Professor Langley's assistant in the pilot's seat. Unfortunately, a part of the structure caught in the launching device, and the machine was abruptly precipitated into the river. It was repaired, and another trial was made in December, with almost identical results. These mishaps were very regrettable, as the Langley airplane was in every way superior to anything else that had appeared up to that time, and his project well merited success.

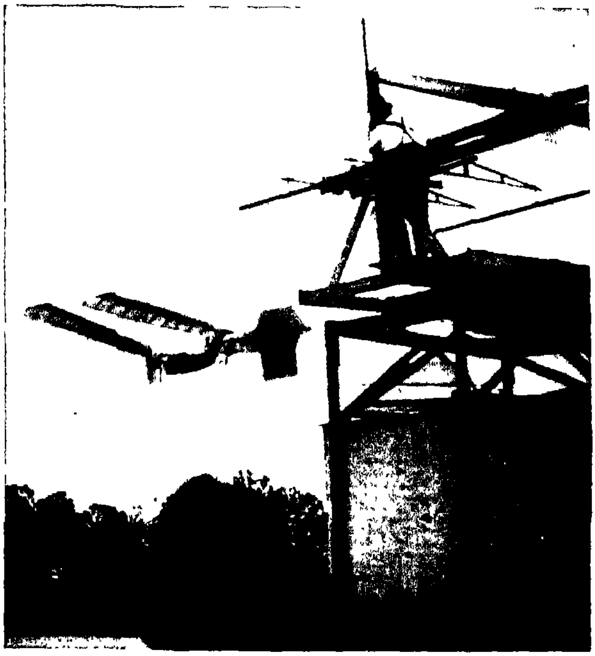


Photo by Smithsonian Institution

ONE OF PROFESSOR LANGLEY'S MODELS IN FLIGHT

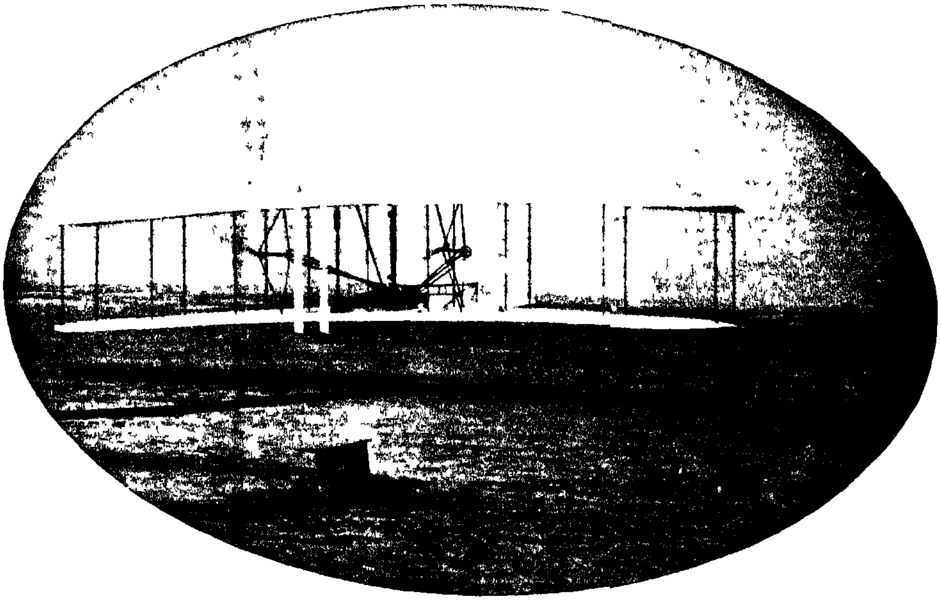
Instantaneous photograph of the aerodrome at the moment after launching, in its flight at Quantico, on the Potomac, May 6, 1896.

About the time that Lilienthal was killed, Mr. Octave Chanute, a prominent American civil engineer, and A. M. Herring, his assistant, began work along lines similar to those which he had followed. They built gliders with one, two, three, and even five planes, on which Herring made a great number of flights. Chanute, however, seeing clearly that shifting of the pilot's weight was but a crude makeshift for maintaining balance, abandoned building operations to search for some means of automatically keeping the machine stable.

Late in the nineteenth century, there were still many scientists of great attainments who believed that it would never be possible to fly a man-carrying machine, and some of them went to great pains to prove this impossibility. By 1900, however, it was clear to anyone who had followed the subject that success was at hand and that it would be but a few years at the most before the dream of many centuries would be realized. Shortly after the death of Lilienthal, two bicycle mechanics in Dayton, Ohio, whose interest had been aroused by the reports of his experiments, commenced the study of flight. It was some time before they were ready to give practical form to their ideas, and when they did so the results were at first rather discouraging. They found that much of the data which had been accepted as correct was seriously in error, and they were obliged to build testing apparatus and determine new values for themselves. Wilbur and Orville Wright did not complete their first glider until 1900. That glider embodied a principle which distinguished it from all previous attempts, for stability was maintained, not by difficult and dangerous acrobatics, but by twisting the planes so that the angle, and consequently the lift, on one side would be larger than that on the other. If, then, the machine started to tilt toward one side, the pilot had only to operate his lever in such a way as to increase the angle of the wing on the low side.

While this idea was not wholly original, their practical use of it was what set the Wright brothers on the road to success After conference with Mr Chanute, they built another glider in 1901, and another in 1902 each being an improvement over its predecessor In the 1902 machine they used a movable vertical rudder for the first time The Wrights' gliders were all characterized by the fact that the operator lay flat on the lower plane, instead of hanging suspended below it They learned too after their adoption of the vertical rudder, that the rudder and wing warping must be operated in conjunction to obtain the best results This simultaneous use of the two controls was the really vital feature of the Wrights' invention, and, having thus attained satisfactory balance, and having secured adequate practice by the making of over a thousand glides, they deemed themselves ready to undertake the construction of a power machine

The brothers accordingly returned to Dayton and began the construction of a 16 horse-power engine, which they applied to an enlarged replica of one of their gliders When the machine was finished they took it to Kitty Hawk, N C, where all their gliding experiments had been performed, and there on December 17, 1903, Orville Wright left the ground, making a perfect flight of 59 seconds' duration Progress from that point was slow, but certain, and two years later both Orville and Wilbur Wright were making flights lasting over half an hour The era of doubt was over and human flight was an accomplished fact During the next few years machines sprang into the air literally by the dozen

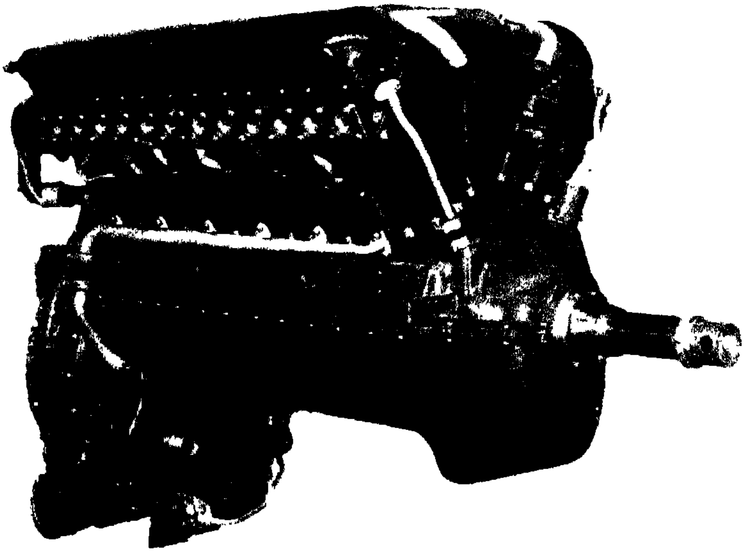


Courtesy of *Flying*
ORVILLE WRIGHT MAKING THE FIRST FLIGHT, DECEMBER 17, 1903

The first man to really fly in Europe was Santos Dumont, whose biplane made several short flights late in 1906 During the following summer, Henry Farman, using a Voisin machine, made a flight of about a mile, and in September, 1908, Farman made a flight lasting 45 minutes His triumph was brief The records of the Wrights had not received much credence in Europe but, in October, 1908, Wilbur Wright took his machine to France, and before the end of the year he had silenced the doubters by remaining in the air for 2 hours and 20 minutes continuously.

Most of the machines now in use are monoplanes or biplanes with one wing above another. Between the wings of our typical biplane there is a body which is carefully made smooth, and pointed at the front and rear in order to make the resistance and power required to drive it through the air as small as possible. The aviator and passengers sit in this body, and it often also contains the motor. The propeller may be either in front of the wings or behind them. Airplanes which have the propeller in front are called "tractors," those with the propeller behind, "pushers."

have been developed. The tail of the machine is usually made up of four planes, two vertical and two horizontal. There is a fixed horizontal stabilizer which maintains longitudinal stability and an elevator by which climb and diving is controlled. There is also a vertical fin which is usually placed above and at the rear of the body. It preserves directional stability while the rudder controls the direction of flight. In modern airplanes the elevator is generally made in two parts, one on each side of the center, so as not to interfere with the rudder but rigidly connected, so that they always operate together.



THE CURTISS-WRIGHT CONQUEROR 600 H.P. ENGINE. THE HUGE GERMAN FLYING BOAT, DO-X, IS POWERED BY TWELVE OF THESE MOTORS

The total length of the airplane is generally a little more than half the span of the wings. In the case of tractors, the body extends back to the extreme rear, but this is not possible in the pusher type with one propeller, as the body, or fuselage as it is sometimes called, would interfere with the propeller. This difficulty has been overcome by the Gallaudet drive, which carries the part of the fuselage to the rear of the propeller on a large tube passing through the hub of the propeller. Today most airplanes are tractors. However many flying boats are pushers and recently a number of light sport planes of this type

The lateral balancing of the machine is accomplished in most cases with ailerons, or little auxiliary wings attached to the back of the main wings near the tips. Sometimes both wings of a biplane have ailerons, but usually they are put only on the upper wing. The ailerons are used in a similar manner to the wing warping employed by the Wrights, one being pulled down to increase the lift while the trailing edge of the other is raised to decrease the lift on that side. Machines are no longer made with wing warping due to the fact that it has been found that this method weakens the wing.

As will be seen, the pilot has three controls to attend to: rudder, elevator, and ailerons. The rudder is practically universally operated by a pivoted foot-bar, something like the handle-bar of a bicycle. The other two controls work through various wheel and lever combinations, a lever being pushed forward when it is wished to make the airplane descend, and a reverse movement being employed when the aviator desires to climb.

As the machine must run over the ground for a considerable distance and attain a high speed before going into the air, wheels are needed; and as it is important to be able to land on a fairly rough surface, it is essential to provide a carefully-designed landing gear with proper means for shock absorbing. Most such devices embody two wheels at the front of the body, and placed far enough below the body so that there will be no danger of the propeller striking the ground, and a short skid or small wheel at the rear which protects the tail from contact with the earth The shock absorbers are usually of the hydraulic type. Sometimes they are merely heavy bands of rubber.

The early airplanes were built almost entirely of wood and steel wire, but these days steel and duralumin tubing is used whenever possible, as these materials have been found to be more uniform in quality, less subject to deterioration, and, in some respects, easier to work than wood.

An airplane in flight acts somewhat like a kite, the string of the kite being replaced by the motor and propeller of the airplane. In order that a surface may be sustained by air pressure, it is necessary that it advance through the air, and some force must consequently be applied to thrust it or hold it forward against the resistance of the exposed parts. In the case of the kite, it is simply held stationary, and the air pressure is furnished by the wind blowing past it. The airplane, however, when flying in calm air, must be drawn forward at a predetermined speed depending chiefly on the size of the wings, the weight of the machine, and the angle at which the wings are presented to the wind, before it will leave the ground.

The air is a very disturbed element, and the aviator must maintain constant vigilance to avoid losing control of his machine, due to gusts or eddies of air. Airplanes are constantly becoming more stable, however, and require less and less attention, on the part of the pilot. Besides, there are various automatic devices, some of them depending on the gyroscope, which will instantly operate the control so as to correct any inclination out of the horizontal.

The marvelously light yet powerful engines aviation has developed

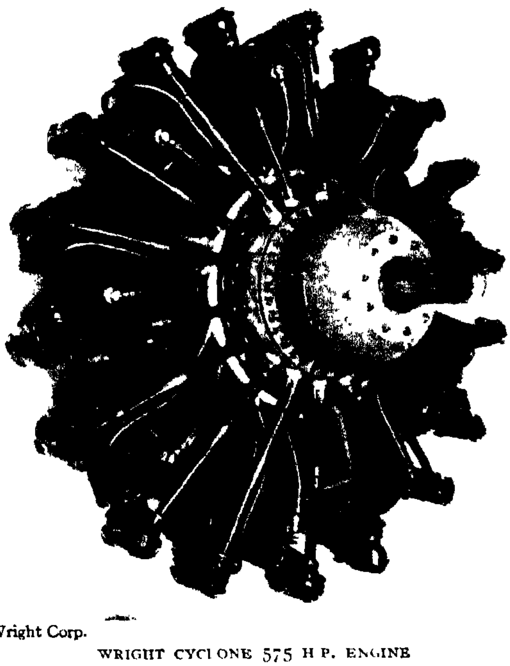
Most airplanes today are driven by gasoline engines working on the Otto four-stroke cycle, but recently some practical Diesel oil-burning engines have been developed. A few years ago the rotary type of motor where the cylinders revolve around a fixed crankshaft were used on light planes but they were found to absorb too much power in turning and are now practically obsolete. The two most popular types of engines are the radial and the V-type. The former, which are air-cooled, are very widely used both on light and heavy planes because of their compactness and relatively large horsepower per pound. They have from three to nine cylinders in a single bank and if in two banks have six, ten, fourteen or eighteen cylinders. The V-type of engine is usually water-cooled and is similar to the ordinary V automobile engine. Airplane engines are wonderfully light. Before the advent of the airplane and automobile, 10,000 pounds was a fairly low weight for a 100 H. P. engine, but motors are now constructed with as low a ratio as $1\frac{1}{2}$ pounds per H. P. A good airplane engine has a long life and should last 500 to 700 hours with the renewal of some of the minor parts.

Types of airplanes seen at the aviation fields today

The airplane most frequently seen today at aviation fields is the two-seat military tractor biplane or a commercial modification of it. Similar machines are also made in smaller sizes carrying only one man. These are used for scouting and fighting, and make speeds in some cases as high as 160 miles an hour.

TWO MODERN RADIAL ENGINES

WRIGHT WHIRLWIND 240 H P ENGINE



Photos Courtesy of Curtiss-Wright Corp.

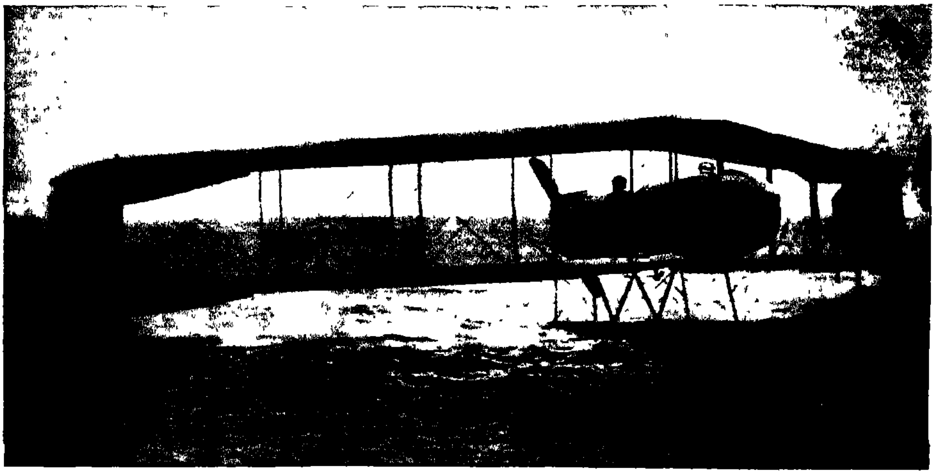
WRIGHT CYCLONE 575 H P. ENGINE

Colonel Lindbergh's famous Lockheed Sirius plane in which he and his wife flew to Japan is powered by this model engine.

The other extreme is the multi-motored plane. This type has from two to nine engines, and one or more propellers, each driven by from one to three engines. The larger machines show a great variety of wing arrangement and construction. They have the advantage of greater endurance and carrying capacity for a given size of crew and, in some cases, due to the ability to fly after one or more motors have failed, are more reliable than the smaller, single-engined ship. The engines may be set out on the wings in nacelles, with propellers mounted directly on the engines, or the latter may be housed in the fuselage with the propellers on the wings.

A number of catapult-like devices have been invented, too, which permit the projecting of the airplane directly into the air from the ship's deck in case circumstances forbid lowering it into the water.

The introduction of the airplane carrier, a large, fast vessel with a flat unobstructed deck, which airplanes can use as a take-off and landing stage, has fostered the development of a third type of airplane, the amphibian, which can operate from either land or sea. The ordinary land type, too, is often equipped for operating from warships with emergency flotation bags of balloon fabric inflated with air. When uninflated they fold into or against the fuselage.

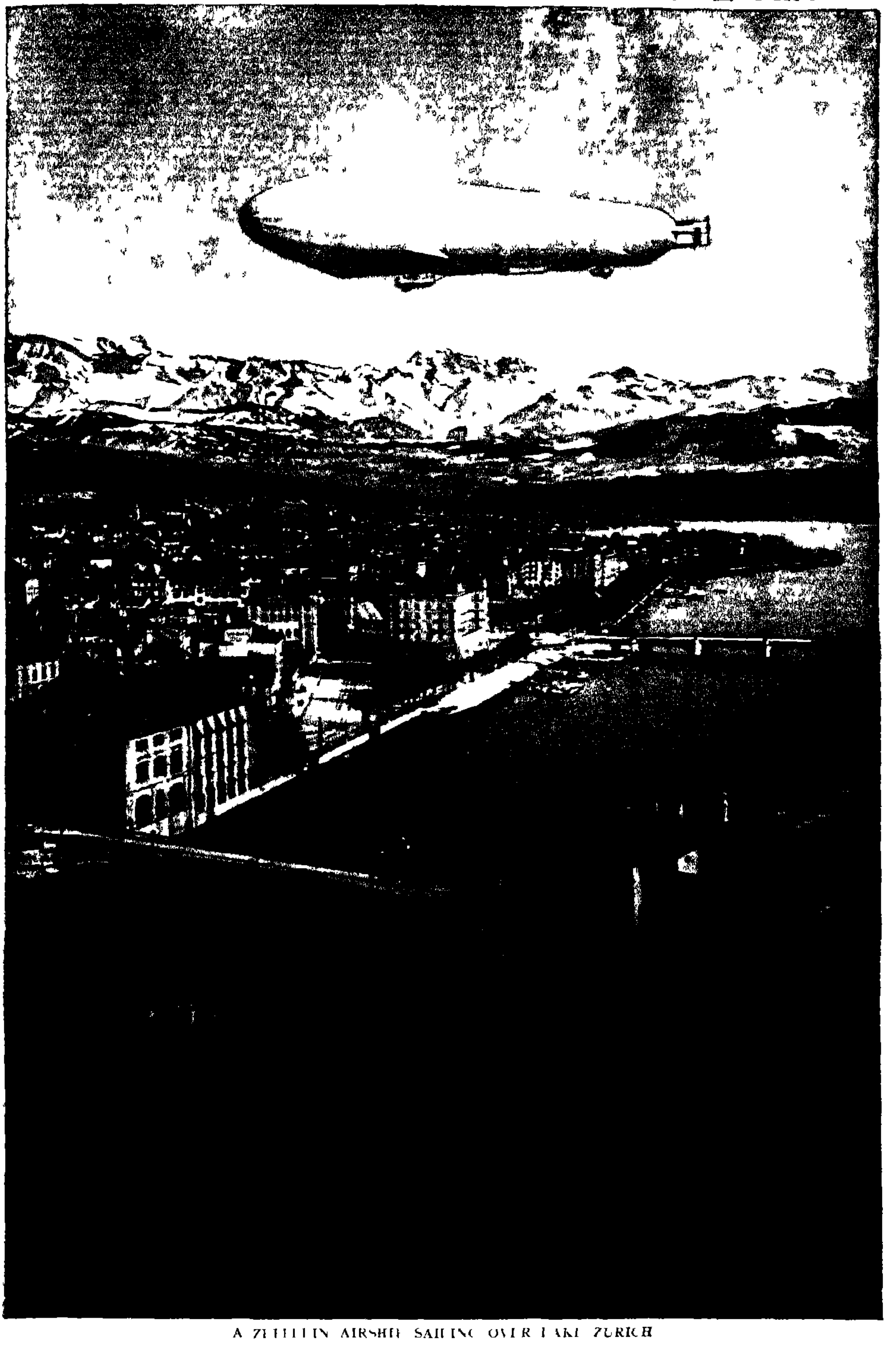


THE BURGESS-DUNNE HYDRO-AIRPLANE
An inherently stable seaplane, requiring no attention except to steer

Of particular interest to Americans, owing both to its usefulness in the defense of our long coast-line and its application to sport, is the hydro-airplane and the flying boat, invented by Mr. Glenn H. Curtiss. These machines rise from and alight upon the water instead of the land, and are able to manœuver safely in a sea which would make the average small yacht quite uncomfortable. They make an ideal sporting vehicle, as they combine all the thrills of the fast motor boat with those of the airplane, and are virtually safe, as the water always presents an easy landing place in the event of engine or other trouble. They can be carried by naval vessels, and lowered over the side with a crane.

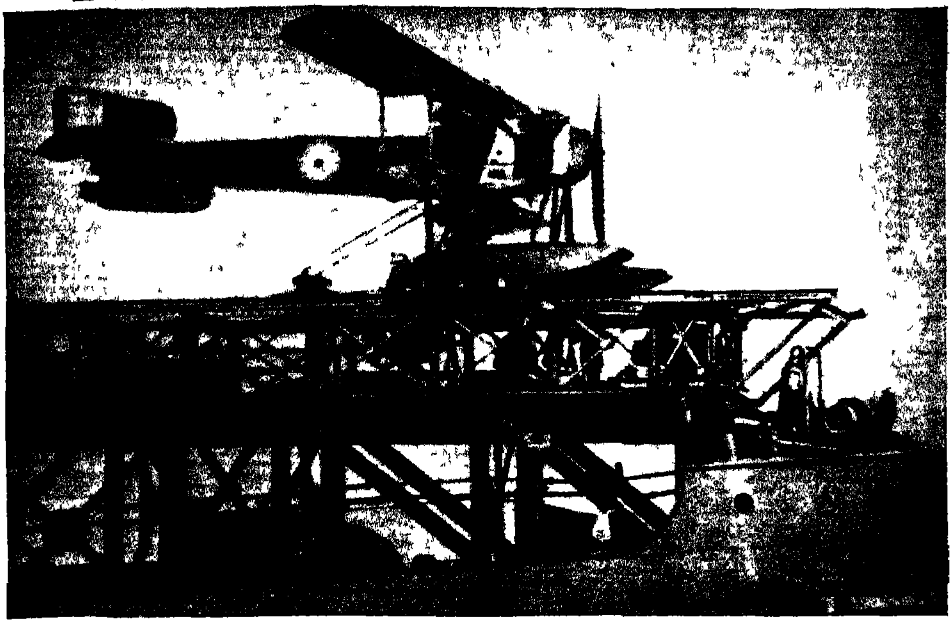
Today the airplane attains speeds of 300 miles an hour, several times that of the fastest-flying bird of which we have any knowledge. It has climbed to a height of over seven miles above the surface of the earth, and can ascend to a considerable altitude at the rate of nearly 2000 feet a minute. It has conquered the most formidable mountain ranges. It has crossed the Atlantic Ocean, and has made other famous flights, notably from England to Australia and from Rome to Tokyo. A man has remained in the air for more than 26 hours continuously. During the course of the Great War, raids far over the enemy's territory for the purpose of dropping bombs were of almost daily occurrence.

THE NEW HIGHWAY THROUGH THE AIR



A ZEPPELIN AIRSHIP SAILING OVER LAKE ZURICH

LAUNCHING A HYDRO-AIRPLANE AT SEA



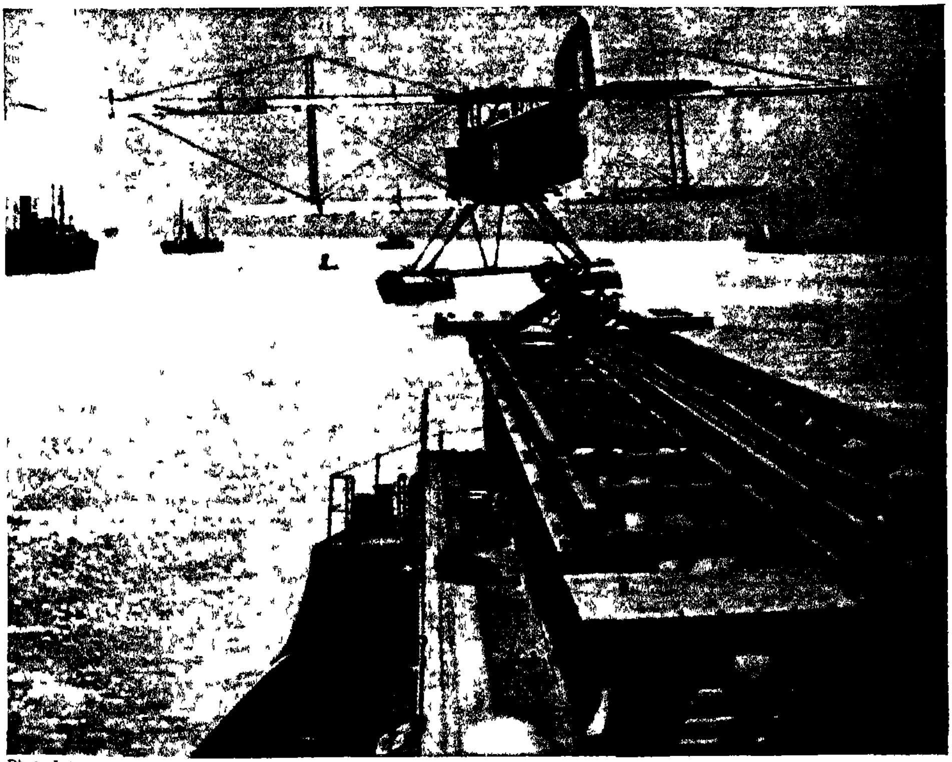
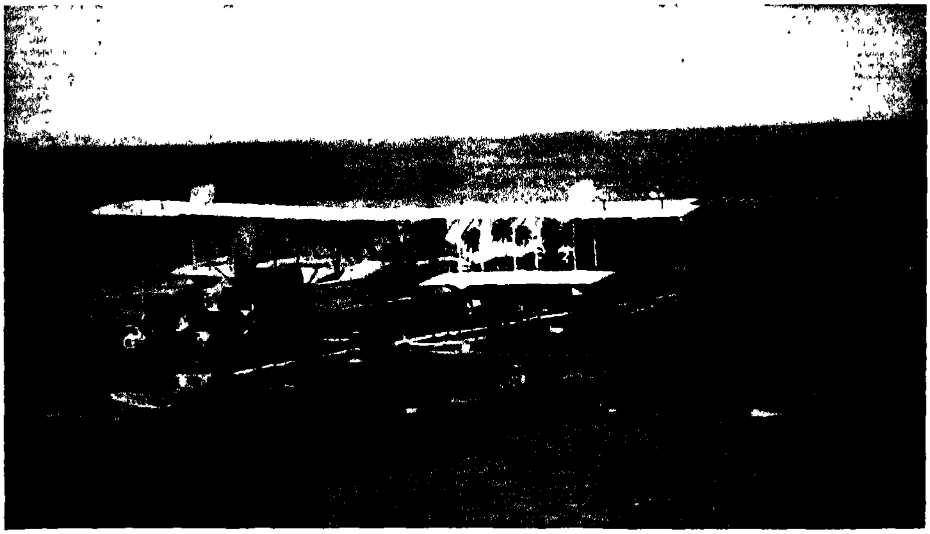


Photo International Newsreel

The upper picture shows the hydro-airplane in position on the launching platform. The picture below shows her leaving the platform, launched by means of a powerful catapult operated by compressed air.

Numerous routes have been established on which the airplane is used to carry passengers and mail, and it will undoubtedly be used for these purposes to a much larger extent in the future, especially over the water and over extremely difficult country, such as deserts and frozen plains, where transit has until now depended upon such primitive, slow, and uncertain means as the caravan, pack-team or dog-sledge. Airplanes are profitably employed by forest rangers in watching for fires, by inspectors patrolling electric transmission lines, and by the coast guard in looking for and carrying lines to wrecked ships.



© Photo Aeromarine Airways

THE "HIGH-BALL EXPRESS" — MIAMI-BIMINI CROSSING

Up to this time, the military uses of aircraft have been of supreme importance, but its utilitarian ends will receive more and more recognition as time goes on. Recently farmers have used them to cover their fields with a dust which destroys insect pests.

During the first few years after the accomplishment of flight, airplanes were designed on somewhat hit-or-miss principles, and their carrying capacity, speed, etc., were determined by actual trial in the air, with the natural result that machines which looked fine often utterly failed to perform the tasks required of them, and even refused to leave the ground at all. As time went on, however, such haphazard methods of design were abandoned. All over the world laboratories have been built for the purpose of aiding designers and, as a result, the performance of a machine can now be prophesied almost exactly before the construction is started. It is even possible, in many cases, to test the stability of a new design by means of a model in an aerodynamic or wind tunnel laboratory, thereby avoiding expense and danger to the pilot. Wind tunnels are long tubes, 3 to 7½ feet and over in diameter, and having at one end a blower which draws through the tube a steady current of air at speeds of from 20 to 100 miles and over an hour. About midway of the tube, mounted on the floor below it, there is a very delicate balance with two weighing arms. At right angles to these two arms is a third, projecting up into the tube, or tunnel proper, and the models to be tested are fixed to the end of this. The air is then drawn through at varying speeds, and the forces on the model in two planes at right angles, corresponding to the lift and head resistance of the airplane, can be found by weighing them on balance arms. To make stability investigations other and much more complex pieces of apparatus are necessary.

Dirigible non-rigid balloons, and their gradual development

There is another type of aerial vehicle which, though it has not had so wide a vogue as the airplane, yet is of great value for certain purposes. This is the dirigible balloon. The dirigible is the natural outgrowth of the spherical balloon, which was invented by two Parisian papermakers, Stephen and Joseph Montgolfier, in 1783. They filled their balloons with hot air, which is, of course, of no use for voyages of more than a few minutes' duration, as the air cools. A little later in the same year, the physicist, M. Charles, averted this difficulty by using hydrogen gas contained in an envelope of varnished silk, and the form of the spherical balloon has not changed materially from that day to this.

Within a year of this time several attempts at constructing dirigibles were made, and one of them, propelled by great oars and with a rudder for steering, achieved fair success in calm air. This was the production of the Robert brothers, who introduced a novelty which still distinguishes a large class of dirigible balloons. A spherical balloon, since it is motionless with respect to the air, has no unbalanced pressures on its surface, and the interior can consequently be left in free communication with the atmosphere. When we undertake to drive it ahead, however, the resistance of the air to this forward motion tends to collapse the bag, and this collapsing tendency must be opposed either by building a rigid framework inside the balloon, or by sealing up the bag and keeping the gas pressure inside a little higher than atmospheric pressure. In order to avoid any loss of gas, a ballonet, or little air chamber, is inserted in the gas-bag, and the gas pressure is regulated by pumping air into, or releasing it from, this ballonet, and this was the device invented by the Robert brothers to make certain that their balloon would keep its shape.

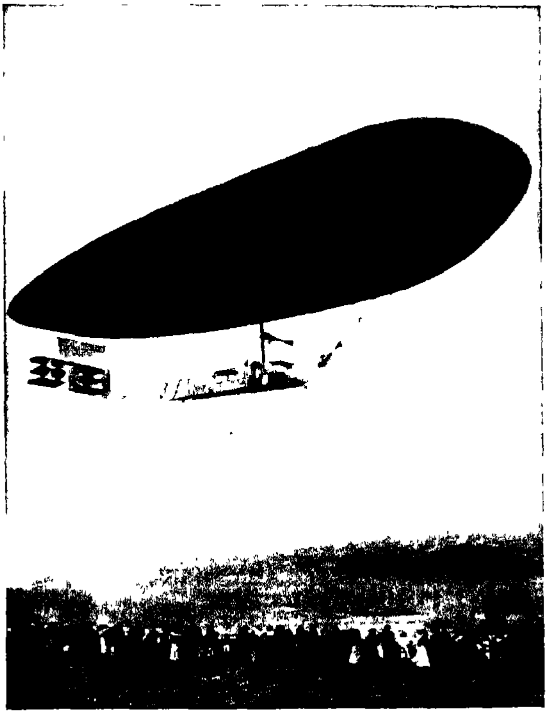


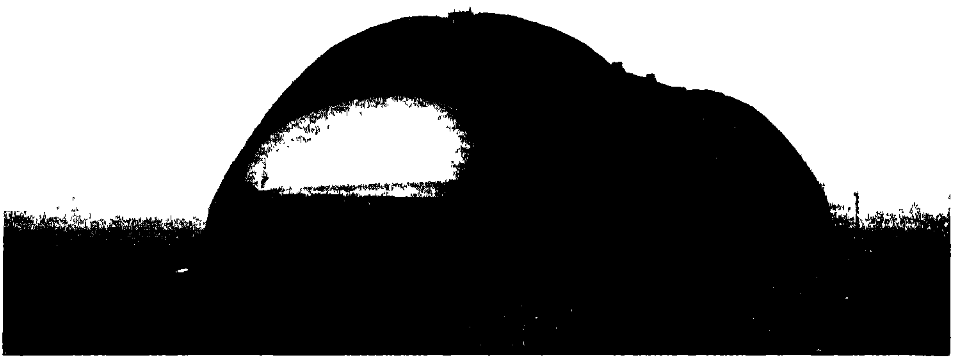
Photo Edwin Levick, N. Y.

A FRENCH NON-RIGID DIRIGIBLE

In 1852 Henri Giffard made a successful trial of a dirigible driven by a steam engine developing 3 horsepower. It will be noted that, whereas nearly all the pioneer work in dynamical flight was done in England, the French were the trail-blazers for the lighter-than-air craft. The next important advances were made by Captain Renard, whose dirigible, *La France*, driven by an electric motor, made a number of voyages in 1884 and 1885, showing excellent control and attaining an average speed of about 15 miles an hour on its several flights.

Toward the close of the nineteenth century, the light gasoline engine became practicable for general use, and this lent the same impetus to the dirigible that it did to the airplane. Santos Dumont, the same young Brazilian who made the first airplane flight in Europe, was the first to achieve conspicuous success with a gasoline-engined balloon. He built a large number of dirigibles, overcoming his difficulties one by one, and finally, in 1901, won

the Deutsch prize by flying from the field of the Aero Club of France around the Eiffel Tower and back to his starting point. His balloons, although excellent as a sporting novelty, did not have sufficient power or carrying capacity to be of great military value, and he turned to the airplane, having contributed greatly to the world's knowledge of the dirigible. Various increases in size and improvements in detail were made, especially by the Lebaudy brothers and Major Parseval, of Germany, but little that is radically new has been added to the non-rigid dirigible balloon since Santos Dumont left it.



Courtesy Goodyear Zeppelin Corp.

THE U. S. S. AKRON, LARGEST RIGID AIRSHIP IN THE WORLD, BEING "WALKED OUT" OF THE GIANT AIRSHIP DOCK AT AKRON, OHIO, FOR THE FIRST TIME

The rigid dirigible and its war record

We have now to consider a radically different type, the rigid dirigible. This is almost entirely the fruit of German labors, and is better known to the general public under the name of "Zeppelin."

Count Ferdinand von Zeppelin (1838–1917) who was military observer for the German army with the Army of the Potomac in 1863 and as such made his first balloon ascension, was an officer in the Franco-Prussian War. After his retirement from active service he became much interested in dirigibles, and completed the construction of his first in 1900. This, like all the long series which were to follow it, was a true rigid balloon. The outer covering was stretched tightly over a complicated framework of aluminum alloy. Within this framework there are a number of bags (about 17) containing hydrogen gas. Below the framework is suspended the car, carrying the passengers and the engines. This system has the advantage that, by strengthening the frame at the proper points the balloon can be driven through the air at practically unlimited speed without danger of collapse, and the subdivision of the gas container insures against total failure in case of an accident to one compartment. Zeppelin I had 32 horse-power, and made a speed of 20 miles an hour. It was five years before Zeppelin II was ready for trial, and she met with speedy disaster, being practically wrecked by a wind-storm. It was becoming evident that balloons of such vast size (Zeppelin II was 414 feet long) required docking facilities equal to those provided for an ocean liner. Further improvements followed, and in 1908 a military Zeppelin made a voyage of 270 miles at an average speed of 22 miles an hour. The German government, foreseeing great military value, was now backing the Count, and he was able to go on with his experiments, building, wrecking, and rebuilding balloon after balloon without the financial worries which had earlier harassed him.

Count Zeppelin's most serious rival in his chosen field was the Schutte-Lanz firm. The framework of their balloons, instead of being aluminum alloy members riveted together, is of wood braced with piano wire, after the fashion used in airplane construction. In *1910*, a regular passenger service was started between German cities, and this was kept up until the outbreak of the war. Zeppelins were used.

The German authorities had confidently expected great things from the rigid dirigibles in a military way, but they failed to develop the hoped for value. They are able to carry large weights, and the possibility of hovering over one spot is an advantage, but they are so large as to afford an excellent target for artillery, and so must remain at a considerable altitude. The raids over England served no important military purpose, resulting only in the destruction of private property and the killing of civilians.

Italy's development of the kite-balloon and the semi-dirigible

During the Great War the tremendous activity in aëronautics extended in other countries to lighter-than-air craft and resulted in a number of important developments. Italy developed a kite-balloon of nearly spherical shape which rides quite steadily in moderate winds. These kite-balloons were much used as observation posts, principally for the direction of artillery fire. They were tied to the ground by a cable and rode in the wind like a kite.

Italian engineers have specialized in the semi-dirigible for many years and are considered to have gone farther in this particular field than those of any other country. It was found that these machines were eminently suited to the Italian needs during the war, possessing the ability to travel at greater heights, although never regarded as a particularly speedy type of ship. The ill-fated "Roma," purchased by the United States in 1921, was the largest dirigible in the world of this make. She was 410 feet long, with a capacity of 1,193,000 cubic feet of hydrogen gas, and, fully loaded, weighed 38 tons including ballast, fuel and supplies.

The terrible disasters to the "Roma" and ZR-2 and their cause

The "Roma's" destruction early in 1922, with a death toll of ten persons, occurred during her first trial trip after the installation of new Liberty engines, which had replaced the Italian engines originally used and found unsatisfactory for flight in this country, and was due to the ignition of her hydrogen gas envelop as the ship struck a high tension wire on her plunge earthward after experiencing some mechanical trouble. Helium had been used by the "Roma" on her first flights in this country, but this had been removed and other gas substituted because of the scarcity of helium and the extreme difficulty of providing a sufficient quantity for operating the giant airship. The "Roma" differed from the ZR-2, which was destroyed in the greatest disaster in aviation history, on her final test trip before being accepted by the United States government for delivery in this country, when she fell over Hull, England, in 1920, in having a rigid framework running along the under surface of the bag, thereby gaining many of the advantages of the rigid dirigible at a less expense in weight. The ZR-2 was 700 feet long and had a capacity of 2,750,000 cubic feet of gas.

Recently the U.S.S. Akron, the largest dirigible in the world, has been completed for the U. S. Navy. It is 785 feet long, has a nominal gas volume of 6,500,000 cubic feet and a maximum speed of 83 miles per hour. One of the most novel and picturesque features of its design is the provision made for the storage of five completely assembled airplanes. Helium is used as the lifting gas which makes it possible to house the engines within the hull of the ship.

Such, in brief, is the story of aërial navigation. It would require a bold prophet to venture a guess on what the future may bring forth, but no one can doubt, after scanning the progress of the past ten years, that the effect on our civilization will be very great, or that the use of aircraft of all sorts will open up hitherto undreamed-of fields.

THE INCREDIBLE NATURAL WEALTH AWAITING DEVELOPMENT IN CHINA

China, now awaking to her opportunities as the most numerous nation on the earth, has enormous deposits of coal and iron, and it is quite probable that she may be the richest country in both these commodities. Seventy miles below Hankow, the city set on fire in a recent revolution, there exists one of the richest iron-mines in the world, where the ore exposed on the surface is estimated at five hundred million tons. The exploitation of this vast natural wealth, as by the enormous Hunyang Iron and Steel Works at Hankow, shown in this photograph, may lead to a great industrial transformation in the Far East.

THE INDUSTRIAL FUTURE

A Survey of the Lesser Nations and the Resources of Coal Power Which Will Determine Their Position

HOW COAL MAY TRANSFORM THE WORLD

OUR survey of the great world of work has shown us three great industrial and commercial Powers standing out with an almost incredible domination resulting from the application and development of native power supplies by gifted white races. We have also seen that the world's resources are not as yet by any means fully developed, and that there is the possibility of great changes, both in regard to relative production in known power areas, and the commercial utilization of powers and resources yet dormant. The world as it is demands our first attention, however; and we pass from the world's industrial leaders to the many nations, great and small, which, either because they do not possess in sufficient amount the means of carrying on large-scale machine industry, or because their peoples are either not gifted in the arts or are not developed in them, are less industrialized than America, Great Britain, and Germany, and relatively more engaged in agricultural pursuits.

It would, of course, be a profound error to value lightly the work done by a nation which is unable, for reasons that it cannot control, to build up industrial centers filled with the smoking factory chimneys which half a century ago a great French statesman coveted for the then unpolluted skies of France. The development of coal-power by a nation fortunate enough to possess it spells what has been termed the "Industrial Revolution," and industrial revolutions are fraught with terrible dangers to a people. Machine industry concentrates the population in towns which, without the application of almost superhuman foresight, may easily become areas of social and physical degradation "where wealth accumulates and men decay."

Great Britain, the first nation to develop machine industry, has suffered sorely in this respect, as all pioneers must suffer. The United States, although developing industrially later, and with the experience of Great Britain to guide and warn it, has by no means wholly escaped the consequences which arise from the rapid and little regulated growth of industrial centers. We can only note these things in passing here, for they will receive full treatment in another section of this work, but the close connection of economic and social science at this point should be fully appreciated. Commerce is a mighty branch of the activities of man, and to be scientifically regarded as part of what Pope termed the proper study of mankind — Man. Regarding trade as an instrument for the building of men, and not merely for the distribution of wealth as defined as commodities having value in exchange, we realize the close connection of industry and commerce with hygiene and sociology.

On another page is a clear statement showing the present relative position of the world's power producers, great and small. It will be seen that the contrast which obtains between the major and the minor coal producers is a very striking one. It must be insisted, however, that this test by present production is conclusive as to the future in the case of the European nations alone. We see France, Czechoslovakia, Russia, and Belgium heading the list of the minor coal-producing nations of the world.

But they do so mainly because they are white nations, possessing a high degree of civilization, which have developed such power resources as they possess. It does not follow, because these nations occupy such a high position as compared with those that follow them in the list, that the figures of present production by any means represent in their proper proportions the *potential* powers of the various contributors to the grand total of nearly a billion and a half tons of coal produced yearly by all the world. We shall see, as we proceed, that it is highly probable that Asia will be as great as, and perhaps much greater than, Europe as a natural power area in the time to come. It is a certainty which raises many considerations, political as well as industrial and commercial, of the highest importance to the world at large.

In a previous chapter we examined the power resources of Germany and of Great Britain, as well as of the United States. We saw that Germany's coal was in some respects greater in extent although inferior in location to that possessed by Great Britain. Before the war the nation which stood next to Great Britain and Germany in European coal production was Austria-Hungary. But although she led France, Russia and Belgium, her production was not so great as Belgium's in the power value of coal, because it consisted as to more than two-thirds of brown coal or lignite, which is greatly inferior to black coal in heating value.

The coal power resources of the new state of Czechoslovakia

By reason of the partitioning of Austria-Hungary by the Treaty of St. Germain, Austria and Hungary retain only relatively small coal deposits. The bulk of the coal reserves of the former empire are included within the boundaries of the new state of Czechoslovakia. Within Czechoslovakia lies the large part of the Ostrau-Karwin field, which is really a part of the great Silesian field. The Ostrau-Karwin deposits consist of over three hundred seams ranging from eighteen inches up to twelve feet in thickness, of which over a hundred are commercially valuable.

Jugoslavia controls the great brown coal deposits in the Trifail District and the Bosnian veins near Zenica and Kreka, and furthermore it can import easily by sea. Hungary has left only the Fuenfkirchen mines, the Totis brown coal deposits, and the Salgo-Tarjan. Its production cannot supply its own demands. Austria must import four-fifths of its coal from foreign countries, despite the fact that there are some large mines in Styria and Upper Austria. Only five per cent of the Austrian production is black coal, the rest being lignite of rather inferior quality. The only black coal mined in Austria comes from Gruenbach in Lower Austria, and this is not of the highest quality.

A comparison easily overlooked in spite of its overwhelming importance

France is, after Germany, the greatest bituminous coal producer in Europe, and has valuable deposits which, combined with recent development of her water powers, make her, in point of present power utilization, the fourth great industrial nation. Coal of commercial value is found in the north, in the center, and in the south of France, and there are also some valuable deposits of lignite. The national production has not advanced very rapidly. As long ago as 1890 about 26,000,000 tons were produced, and after twenty years' further development the total was but 10,000,000 tons higher. The most valuable coal field is that of the north, where the seams are continuous with those of Belgium. Actually great, but relatively small, the power area of France suffers by comparison with that of Germany; and the comparative advance of Germany in recent years may be very largely accounted for by the French handicap in this supreme natural advantage.

Very soon after the Great War was begun in 1914 the German armies, acting upon plans long considered, were in possession not only of all the productive coal mines of Belgium and the most productive of Russia, but also of most of the coal fields of northern France. Half of the normal French output of coal came from mines thus in the possession of the Germans.

The loss of the continental coal fields a great handicap to the Allies

This unfortunate fact meant a very great additional burden put upon the Allies in the conduct of the war. France had to rely upon England for the necessary supplies of coal. England also during the war, *helped in some measure by the United* States, sent large supplies of coal to Italy as well as Spain and other neutral nations. By the treaty of peace France not only regained her northern coal fields but was also given ownership of the relatively small but rich mines of the Saar district, just east of Lorraine. Although the ownership of the Saar mines is vested in France, the government of the district in which the mines are located is in the hands of a commission chosen by the Council of the League of Nations. Ultimately the inhabitants of the district are to decide whether they wish to go back to Germany or become part of France.

The European coal situation was disarranged by the fact that the German armies, before withdrawing from northern France, seriously damaged the largest and best of the French coal-mines by destroying buildings and machinery and by flooding the mines themselves. It was as partial compensation for this wanton destruction that the Saar mines were transferred to France. Furthermore, Germany was obliged by the terms of the treaty to deliver annually to France large amounts of coal produced in German mines. In the meanwhile the rehabilitation of the French mines has progressed steadily, so that France is rapidly regaining her former position as a producer of coal. It is not true, however, as some have thought, that the acquisition of the Saar mines and the restoration of production in northern France will render France entirely independent in respect to coal for her industries.

By the return of Lorraine, France has become possessor of the largest and most valuable iron ore deposits of Europe; in fact she may be said to have more or less of a monopoly of the available iron ores of continental Europe.

Now, as everyone knows, the smelting of iron ore requires coke. Before the war the supply of coke from French coal fields did not suffice even to smelt the iron produced in that part of Lorraine which had been retained by France. The coal of the Saar fields will not perceptibly affect the situation. The Saar coal is of good *quality for heating purposes. But it is* not good coking coal. Before the war the iron ores of the Lorraine district, whether in German or French territory, were smelted very largely with the aid of coke from the wonderful Westphalian district of Germany. The iron and steel industry had reached a high state of development, both in Westphalia and in Lorraine. The same cars that brought Westphalian coal to the blast furnaces of Lorraine took back Lorraine ores to the Westphalian furnaces. It is hard to find anywhere a better example of the natural and inevitable economic cooperation of different industrial districts. It is impossible that the shifting of the political boundary between France and Germany will materially alter this natural and inevitable arrangement. France will continue to import German coal and Germany will import French ore

The small output of the enormous coal *fields of* Russia

A minor point to be borne in mind when comparing the fuel of France with that of, say, England, is that France, for climatic reasons, does not need to spend so much strength or income in the getting of coal for the purposes of domestic heating. This somewhat improves her comparative position, but it does not atone to her for her comparative lack of native power.

Russia comes next under review. The enormous territory of Russia in Europe includes some great coal areas, larger indeed than those of Great Britain, but not nearly as valuable. Thus, the Donetz coal field alone has an extent almost as great as that of all the coal fields of the United Kingdom together, but not only are the seams thin but the coal is very poor in quality.

The Moscow coal field, too, has an area of 9000 square miles, but many of its thin seams are too deep to be commercially valuable, and they are therefore not worked. We need not be surprised, therefore, if Russia, in spite of her enormous coal fields, produced before the war but some 25,000,000 tons of coal a year, and that in the recent years of political and economic turmoil her output has been very much less than that figure. The facts in this case are another reminder of the importance of possessing not merely coal, but easily won coal; and it cannot too clearly be remembered that in the world of commercial competition coal which cannot be competitively worked does not, for practical purposes, exist at all. Not content with its economic position, the old Russian government took active steps to develop the water-power in districts such as the Caucasus.

Belgium a striking illustration of the effects of possession of power

The little kingdom of Belgium, which produces very nearly as much coal as the great country of Russia, is perhaps the most striking illustration the world affords of the extraordinary effects produced by the possession of power. Belgium is the smallest kingdom of Europe, but she contains the densest population. Her total area is but a little over 11,000 square miles. She is thus a little smaller than the state of Maryland, yet the last census showed her to have a population of over 7,500,000, or nearly 700 persons per square mile. The explanation is chiefly to be found in the fact that Belgium has about 1000 square miles of rich coal area. In addition to the basins of Hainault and Liége, which have long been profitably worked, important fresh discoveries have recently been made, the new coal field of the Campine containing, it is estimated, over 500 million tons of coal. Belgium, as a consequence, is highly industrialized; and the effect upon her external trade is to make her, for her size, a very vigorous exporter of manufactures, which in many cases compete effectively with those of the great industrial countries.

The smaller countries of Europe that have very little coal

Unfortunately for Europe and the white races generally, and especially so for the countries concerned, the remainder of Europe possesses very little coal. It will be seen that Spain, Holland, Italy, Turkey, Sweden, Bulgaria, and Roumania are indeed named in the table on the next page, but little more than named. Between them they produce in a year much less than 10,000,000 tons of coal, or far less than the mere annual *variation* in American production. As a consequence, the population of these countries is chiefly engaged in agriculture.

Spain, which bulks most largely in the remaining European states in the coal list, has been estimated to possess mines containing 3,500 million tons of coal. What this means may be realized when it is remembered that the United States is now producing about 550,000,000 tons in a single year — a rate which would exhaust the Spanish mines in seven years. The real meaning of this is that Spain is merely a nominal coal producer. It is a fact with very remarkable consequences.

The Spanish iron mines that are worked chiefly for foreign utilization

Spain is exceedingly rich in iron ore, but because of her lack of power the Spanish iron mines are worked chiefly to provide ore for the furnaces of other countries. British and other ironmasters compete for the Spanish iron supplies. Often the Spanish iron mines are owned by foreigners, so that in truth an iron mine may be only nominally in Bilboa and only nominally Spanish. Again we have forcibly illustrated the effect upon commerce of the possession of large-scale power. If Spain had the coal mines of the United States, her iron ore would be smelted at home, and Spain would export iron and steel and their products in place of iron ore. Thus by a single but all-important deficiency in her natural endowment Spain falls short of the possibility of attaining the position of one of the leading industrial nations of the world.

COAL PRODUCERS GREAT AND SMALL

(Official figures for 1929)

Country	Coal Produced (Metric tons)
United States	552,465,000
Great Britain	260,832,000
Germany	163,437,056
France	53,736,497
Czechoslovakia	16,521,457
Russia	38,423,000
Belgium	26,931,460
Japan	34,258,000
India	22,495,347
China	* 16,000,000
Canada	12,272,806
Australia	* 9,978,000
Poland	46,236,037
South Africa	13,018,328
Hungary	826,270
Spain	7,058,316
Austria	208,020
Jugoslavia	408,611
New Zealand	1,389,107
Holland	11,581,202
Chile	1,325,611
Mexico	1,054,196
Brazil	* 400,000
Italy	215,640
Dutch East Indies	1,831,504
Indo-China	1,941,310
Sweden	394,975
Peru	219,654
Belgian Congo	102,500
Bulgaria	72,478
Roumania	370,947
Federated Malay States	672,131
Borneo	73,100
Southern Rhodesia	1,036,816
Algeria	16,128

* Estimated.

More remarkable still is the case of Italy. Here is a great nation, with a population of about 42,000,000 people, who in the first part of the twentieth century, and in the age of coal, finds herself almost entirely wanting in the most important factor in modern work. The tiny production figure given in the table refers to lignite and not to coal proper, and even of lignite the production amounts to but a million tons a year — an almost negligible quantity. In view of this fact, the industrial progress of modern Italy can only be regarded as remarkable. It is largely based upon the recent systematic development of her water-power.

The development of "white coal" in Italy and Switzerland

The urgent spur of sheer necessity has prompted Italian engineers to develop the considerable water-power of the peninsula, and upon this vitally important work a not inconsiderable industrial output has been founded. In northern Italy, many cotton mills have been electrified. Milan is yearly consuming additional electricity based on "white coal."

Great care is being taken not to intrench upon irrigation, this danger being met by a suitable storage system Among the cities of from 10,000 to 50,000 inhabitants now supplied with electricity are Vercelli, Novara, Pavia, Bergamo, Brescia, Verona, Voghera, Alessandria, Mantua, Vicenza, and Intra. Many of these have become important manufacturing centers through hydro-electrical installations. The city of Como, one of the principal silk centers of Europe, draws power from the lake of Lugano through a line 27 miles long. Verona, which the mind instinctively connects with one of the world's most famous romances, has prosperous factories fed with electricity from water-power. In Venice, too, there are important electrical developments.

Similarly Switzerland has endeavored to develop "white coal" for want of the black variety. She has a little inferior anthracite, but the total area of all her available coal and lignite measures is little more than 200 acres. A great deal of good work has been done in developing water-power, but, even so, she is hard put to it to maintain some of her chief industries. The most telling example is the watch industry. For centuries the Swiss watchmaker has justly had a world-wide reputation based on ingenuity and skill. Yet we find a recent official report on the Swiss watch industry stating that the transfer of this branch of trade across the frontier was a question engaging the attention of those concerned; and that various suggestions were being considered for arresting such a movement and preserving this important and characteristic industry for the Swiss people.

The natural wealth of countries which cannot make use of it

The case of Sweden, which figures in the table for an annual coal production of 400,000 tons, is similar to the case of Spain. Sweden has been estimated to possess 40,000,000 tons of coal—an amount, that is, which is produced in the United States in a single month. Consequently Sweden, which, like Spain, is exceedingly rich in iron ore, is not a great iron-producing country — although her charcoal iron has a fine reputation for certain special uses — but a great iron ore exporting country. Scandinavia is a rich iron land, and the best Scandinavian deposits, having few equals in the New World or the Old, are found in Sweden. Germany, and to a less extent Great Britain, import enormous quantities of ore every year. Before the war Germany alone took nearly 2,000,000 tons a year of Swedish ore, which she mixed to advantage with the lower grade ores from Lorraine and from various German districts. During the war German dependence upon Swedish ore was redoubled. True, her armies had brought the rich ore fields of French Lorraine back of the German side of the battle-line. But these ores, despite popular rumors to the contrary, were never utilized largely in the making of German munitions.

For the production of the needed high-grade munition steel the Swedish ore was invaluable. The Allies wasted a good deal of effort in the fruitless attempt to weaken Germany's position by putting an end to this traffic.

Again we see the natural wealth of one country of more use to the foreigner than to the native, because the foreigner possesses the means of power control denied to the native. In recent years Sweden appears to have awakened to the economic disadvantages which she suffers, and there has been much activity in developing her estimated 6,500,000 horse-power in the form of potential water-power. About a fourth of this is now in use.

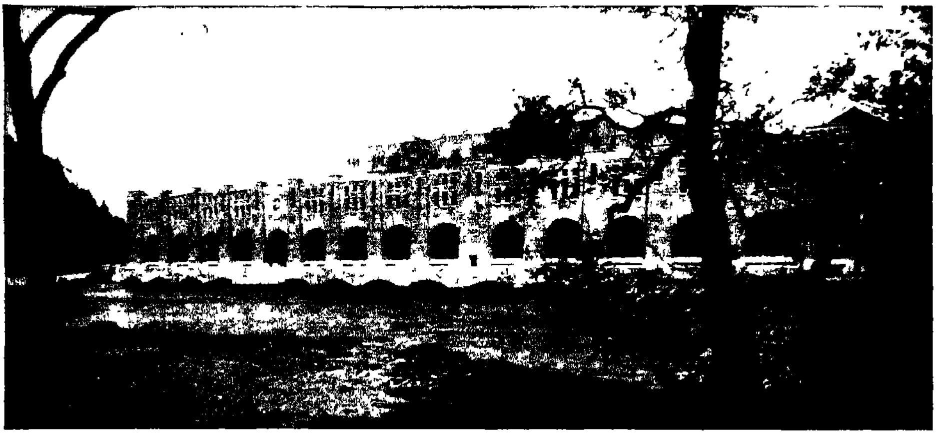


Photo from National City Bank, N Y

TROLLHATTAN POWER STATION, OWNED BY THE SWEDISH GOVERNMENT

It is equipped with 13 turbines and generators averaging 115,000 K W.

How Sweden is adding to her national store of power

The Swedish government has itself led in this important development of natural resources. The government-owned power stations at Trollhattan, Alfkarleby, and Porjus are as modern and as efficient as any in the world. The hydro-electric power developed in Sweden is utilized in hundreds of different ways. It furnishes light for homes and barns in rural communities; it drives farm machinery; it runs lumber mills, paper mills, textile mills, and iron and steel mills; it supplies, in increasing measure, the motive power for Swedish railways.

The sister Scandinavian kingdom of Norway has no coal output, but is the fortunate possessor of water-power which is rapidly developing. Her water-power resources are estimated at 15,000,000 horse-power, of which nearly 2,000,000 is already being utilized. As in Sweden, electric power is applied in nearly all lines of industrial and domestic activity. In one respect, however, Norway, with its cheap electric power, has advanced further than any other country. With wisdom and forethought, it has made a marked advance in the electro-chemical and electro-metallurgical industries. The most important products are calcium carbide and various nitrogen compounds. One of these products, Norwegian saltpeter, so called, has a large and increasing use as a fertilizer, and is shipped to nearly all parts of the world. Sodium nitrite, used in dye-works, is another important export product of Norwegian "white coal." During the war the nitrogenous products of Norway were in great demand on the part of the belligerent nations, by reason of their use in explosives. Science has transmuted Norway's water-power into a natural resource comparable to Chile's nitrate deposits.

ONE OF NORWAY'S FINEST ELECTRO-CHEMICAL PLANTS

Photos from National City Bank, N. Y.

CARBIDE WORKS IN A NORWEGIAN PORT

Denmark, Holland, and Portugal are very poorly furnished with either coal or water-power. Turning to the southeast of Europe, there are some fair deposits of fuel, chiefly lignite, in the Balkans, but the quantities are almost negligible in relation to the needs of large-scale manufacturing.

The entire continent of Africa is very poorly furnished in coal. South America is a little, but only a little, better supplied. The Argentine Republic has no coal resources. In the past it has relied chiefly upon British coal. Brazil and Chile have some coal, but it is difficult to reach and it is hardly probable that the quantity is sufficient to provide for the needs of these two countries. Such coal as South America has produced in the past has come mostly from Chile. Colombia and Peru have only small mines; Uruguay has none. South America, so far as we can foresee, must continue to import coal. Its industrial progress must depend, therefore, very largely upon the development and utilization of water-power.

In Brazil the absence of available coal is a peculiarly serious problem, because Brazil has in the iron deposits of Minas

Geraes what is generally thought to be the largest and intrinsically the richest iron ore deposit in the world. On account of the distance of these deposits from the coast, the steep grades to be surmounted, and the impracticability of bringing coal to the mines, the development of these wonderful ore beds has been retarded. They remain the world's principal reserve for the future.

In Australasia, New Zealand has a little coal, but what it has is easily available because the mines are close to the sea. In Queensland, Victoria, and Western Australia, there are coal reserves, but the coal is of poor quality. The best coal in Australia is that of New South Wales, and it is indeed of excellent quality. New South Wales is one of the very few coal exporting nations of the world. It sends its coal to other Australian states and to different Pacific ports.

It remains to deal with the difficult and interesting problem of Asia. It is a striking and significant fact that three Asiatic nations, Japan, India, and China, stand among the first eleven in coal output. Japan has in a very few years risen to the position of a considerable producer. As recently as 1890 her output was less than 3,000,000 tons a year. The Japanese coal fields are supposed to have an area of about one-half of those of Great Britain but they are not nearly as rich in content, and there is no reason to suppose that Japan will ever become a really great producer. We may be quite sure, however, that her resources, for what they are worth, will in the future be worked as energetically as those of the European nations, and we may expect to see Japan take a high place as an industrial power in the twentieth century.

It is when we turn to China that we find a coal nation of the first rank. The small Chinese production is exceedingly misleading as a test of the richness of the coal resources of China. So great are they that it is difficult to exaggerate either their importance or the prospects of Chinese industry which must follow upon their proper development within the next few decades.

The extraordinary richness of China in the source of industrial power

China has a coal area of 232,500 square miles, to realize which we have to imagine a coal field five times as great as the entire area of the state of Pennsylvania.

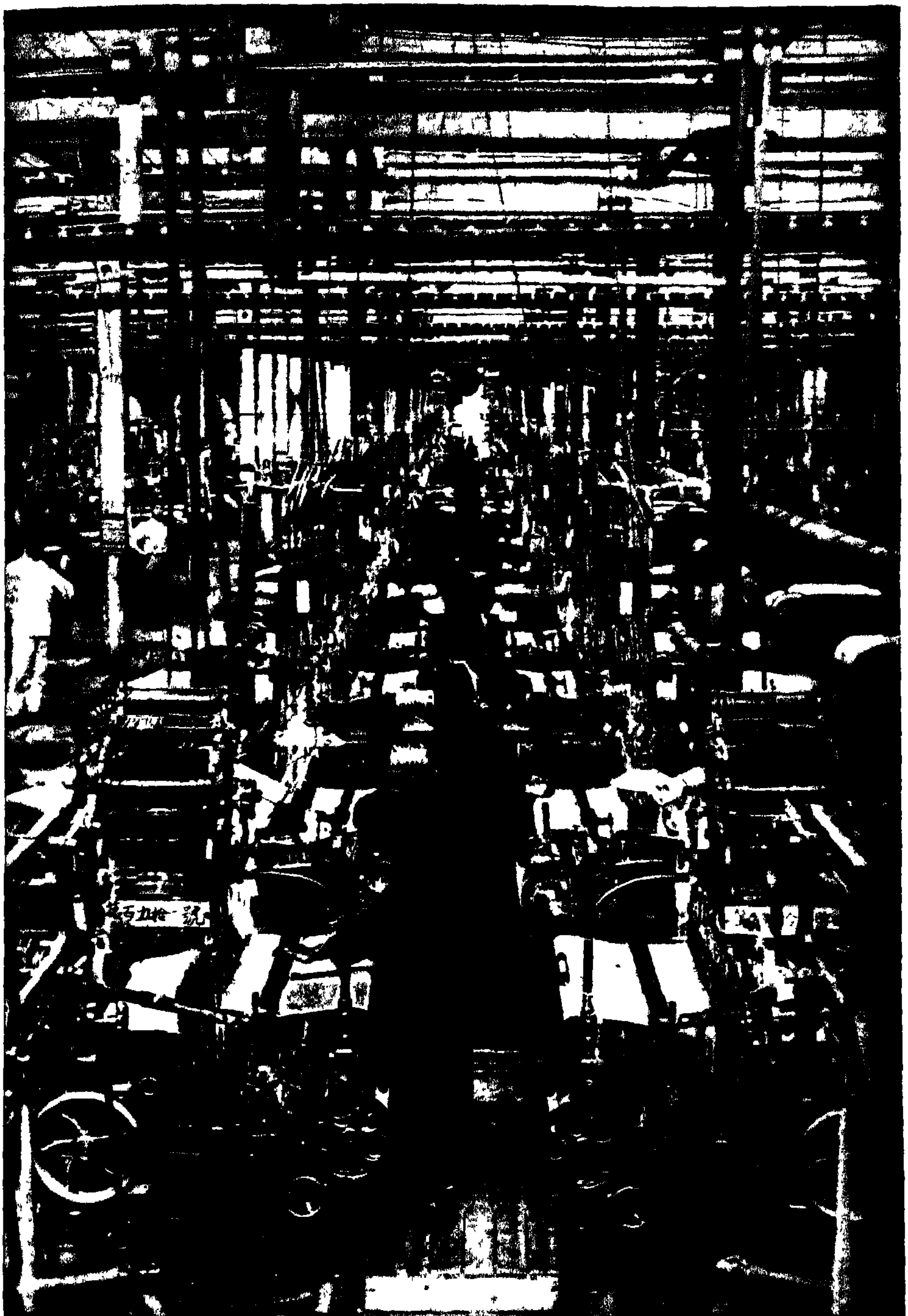
It is probable, too, that this is but a conservative estimate, since exploration can scarcely have been thorough. The deposits are exceedingly rich in available coal; and it is possible that the bituminous coal and anthracite available in China at depths making it commercially profitable to work them are as great as those of the United States. According to the latest estimates, China has available 1,500,000 million tons of coal. While these figures can only be accepted as approximate, there can be little doubt that China possesses at least as much coal as all of the rest of the world outside of the continent of North America. Coal has a wide distribution in China, and there are important fields in the northeast, in the west, and in the south of the republic. In the northeastern field the deposits are magnificent. The average thickness of the beds is said to be, for Kaiping, 18 feet; for Wangping, 35 feet; for Fangshan, 20 feet; for Ping-Ting, 20 feet; and for Tse-Chou, 22 feet. These fields together represent 12,500 square miles of coal, with a content of 350,000 million tons!

The arrested development of the yellow races

The coal fields of Shansi may be the richest in the world; they have an area of 13,500 square miles, and there are several seams of fine anthracite, the main seam being 18 to 27 feet in thickness, and continuous over a huge area.

What has been termed the arrested development of the yellow races is a phenomenon of exceeding interest. It is not merely that the Chinese are a civilized people; they were civilized when northern Europe was peopled with painted savages. China "witnessed the rise to glory and the decay of Egypt, Assyria, Babylonia, Persia, Greece, and Rome, and still remains the only monument of ages long bygone."

INDUSTRIAL DEVELOPMENT IN THE EAST



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SILK FACTORY IN JAPAN

There is no doubt that Japan will take a high place as an industrial power in the twentieth century, and its rapid rise in industry is hardly less striking than its rise in political and military power

Tens of centuries ago, China had attained to a civilization of no mean order. It is difficult to explain why that civilization was arrested, and why in every department of life progress came to a standstill. Why, for example, having won a certain knowledge of astronomy, did the Chinese intellect not pursue the subject to independent discovery of the brilliant revelations of the cosmos made in the far newer western civilization? Why, again, did China, which knew the value of coal long centuries ago, and had such a bountiful supply, not discover what power could be unlocked for the burning of it?

What Marco Polo, the great traveler, saw in China seven hundred years ago

Seven hundred years ago Marco Polo, the Italian, traveling to far Cathay from what was, and is, a coal-less land, found the Chinese using coal for fuel. He crossed western Asia and Tartary, reaching China in 1275, where he was received with great honor by Kublai Khan, being appointed to various high offices, at one time administering a province for three years. He tells us that "throughout this province there is found a sort of black stone, which they dig out of the mountains, where it runs in veins. When lighted, it burns like charcoal, and retains the fire much better than wood; in so much that it may be preserved during the night, and in the morning be found still burning. These stones do not flame, except a little when first lighted, but during their ignition give out a considerable heat. It is true there is no scarcity of wood in the country, but the multitude of inhabitants is so immense, and their stoves and baths, which they are continually heating, so numerous, that the quantity could not supply the demand; for there is no person who does not frequent the warm bath at least three times in the week, and during the winter daily, if it is in their power. Every man of rank and wealth has one in his house for his own use; and the stock of wood must soon prove inadequate to such consumption; whereas these stones may be had in the greatest abundance and at a cheap rate."

Mining, in the modern sense, only introduced into China in recent years

We can imagine that this passage must have been thought a traveler's tale by many of the Venetians who first read their compatriot's marvelous story; today we know that the "black stones" are even more marvelous than they must have been considered to be in the Italy of the thirteenth century. The passage, too, is valuable as reminding us how long the Chinese have been a civilized people, bathing themselves religiously in an age when many European potentates neither drank water nor washed in it if they could help it. Whatever the explanation, the Chinese development was stayed, and not until recent years has mining in the modern sense been applied to this mighty Eastern source of power. Who shall put a limit to the industrial developments of China when once the former Celestial Empire gets under way with modern appliances? Mining and manufacturing are easily transplanted to a new land — "all men can grow the flowers now, for all have got the seed." The foreign capitalist is eager to exploit Chinese coal for his own advantage, but we must remember Chinese coal cannot be developed for the foreigner's benefit alone; it is impossible for China herself not to gain, since the economic power of coal can only be fully developed in the place where the fuel is got. That China is intellectually astir all the world now knows. The great revolution of 1911 was the sign and portent of a stirring of life and of thought which could not be controlled. The Washington Conference of 1921-1922, at which the Great Powers assured to China a freer hand than she had before in controlling her own development, is likely to prove a second great historical milestone in the evolution of China.

Few realize how rapidly industrial developments are proceeding in the East. Many Chinese mines are being worked on modern principles. By far the largest mining company in China is the Kailan Mining Administration, which is owned largely by Belgian capital, although it operates British and Chinese properties.

In recent years it has been producing 3 million tons of coal a year. In Honan Province, the Pekin Syndicate, Limited, a British concern, has important mines at Ching-Hau-Chen. The Pinshieng collieries, largely owned by the Chinese themselves, have been producing a million tons of coal a year. The Funshun collieries, producing two million tons of coal a year, are owned by the South Manchuria Railway Company, which, in turn, is controlled by the Japanese. The Mining Company of Shantung, with a somewhat smaller output, formerly owned by the Germans, has now been returned by the Japanese to China. Of course a good many smaller mines throughout the different coal districts are worked by the Chinese themselves. For some time to come, however, Japanese, British, and American capital will undoubtedly be called upon to coöperate with Chinese capital in the development of these wonderful mineral resources.

China as rich in other minerals as she is in her coal resources

As it is, however, the fringe of Chinese mineral wealth has barely been touched. But the output is rapidly increasing, and it is impossible to doubt that in the course of another generation China will be the fourth coal producer in the world. Thereafter she will gain rapidly upon Great Britain and Germany and will ultimately pass them.

Then will be set up in the Far East mighty centers of modern industrial effort, which will entirely change the position of China in the world of trade and in the category of nations. For China is as rich in other minerals as in coal. Merely to speak of what is known, she has large iron deposits, and it may be surmised that much remains to be proved. On the Yangtze, seventy miles below Hankow, there exist rich iron mines.

The ore exposed on the surface has been estimated at 50,000,000 tons. There are also proved and valuable deposits of copper, lead, tin, mercury, antimony, and zinc, and of gold, silver, platinum, and nickel.

When China's hundreds of millions find and utilize China's power

Other very important minerals found in abundance include petroleum, marble, porphyry, china clay, sandstone, salt, sulphur, plumbago, alum, abestos, and precious stones in variety. We have to imagine what may, what will, be done with all these good gifts when the latent industrial capacity of hundreds of millions of strong and intelligent people is reinforced by the utilization of the potency of a coal area of considerably over 200,000 square miles.

It would be a profound error to suppose that such a change in China as would be necessarily born of modern power development would be of injury to the commercial interests of the Western nations. In the days when China, as we need not hesitate to prophesy, will be a great and flourishing industrial nation, she will make exchanges with Europe and America far exceeding in value her existing commerce. Chinese import trade is now worth but about $820,000,000 a year.

The course of the twentieth century may see this figure multiplied tenfold or more as China builds, upon the sure foundation of power which we have described, a vast and many-sided industry and commerce. It was doubtless the policy of exclusion, and the consequent lack of contact with the intellects of other races, which contributed to that peculiar arrest of growth which marked the history of China. A wider commerce with the world, and the consequent enlargement of the Chinese mental horizon, may give such an impulse to the Chinese people as to reveal unsuspected qualities in what is recognized as excellent material by those who know China best.

In an earlier chapter we saw how commerce and the new contacts and new problems created by commerce shook Europe out of the deadly stupor of the Middle Ages and put it on the way of modern growth and progress. In the same way medieval China, and that means the China of the nineteenth century, has felt the stimulating power of commerce.

THE FASTEST AUTOMOBILE IN THE WORLD

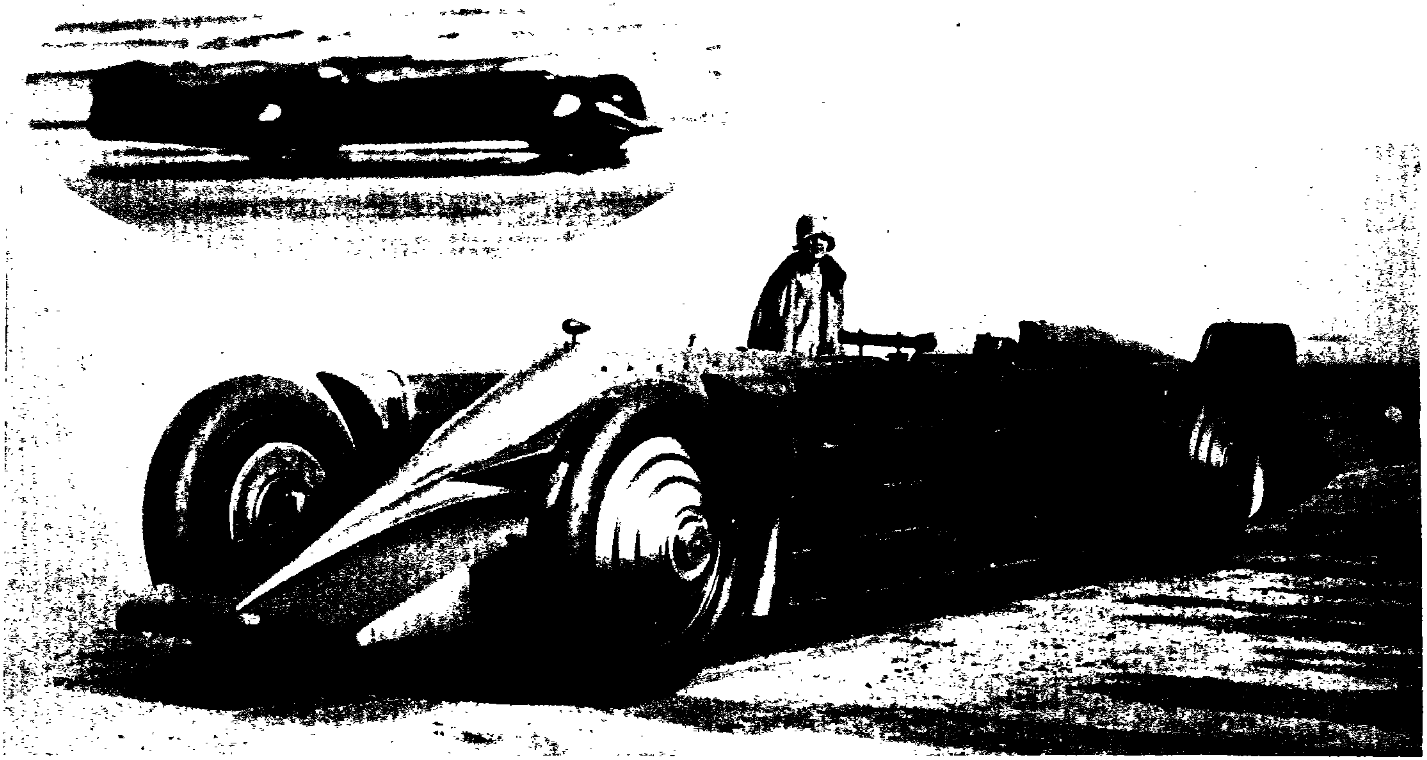


Photo Wide World Photos; inset Acme Newspictures Inc.

Major H. O. D. Segrave at the wheel of his 900-horsepower Golden Arrow at Daytona Beach, Fla., where he broke the world's speed record for automobiles on March 11, 1929. Inset shows the car on its record run in which it averaged 231.36 miles per hour.

BUILDING AN AUTOMOBILE

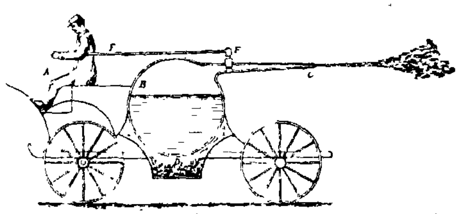
The Wonders of the Machine That Enables a Man to Live Next Door to Everywhere

THE AGE OF THE HORSELESS CARRIAGE

ADVENTUROUS spirits in all times have had a keen desire to fly through the air like the birds, and to traverse the land and skim the sea at great speed and with perfect freedom of motion. Mythology and the early literature of our race abound in stories and speculations pertaining to such accomplishments, but until the invention of the steam engine the best that man could do was to harness the winds to move his ships and utilize animals for rapid transport on land. The invention of the steam engine and of the gas engine has altered all this and has made it possible for us to navigate air and sea and to annihilate distance on land, in a manner that would almost justify the ancient mythological superstitions and the tales of the Arabian Nights.

The period of modern speculation on this problem appears to have begun about the thirteenth century. Roger Bacon, an English Franciscan monk living in that time of ignorance of mechanical matters, wrote in one of his learned treatises: "We will be able to construct machines which will propel large ships with greater speed than a whole garrison of rowers, and which will need only one pilot to direct them; we will be able to propel carriages with incredible speed without the assistance of any animal; and we will be able to make machines which by means of wings will enable us to fly into the air like birds." This most remarkable prophecy at a time when none of the means of its fulfillment were in sight has all come to pass, and it would be interesting to know the grounds on which this philosopher based his predictions.

Bacon made no practical suggestions as to how he expected these things to come about, but in 1680 Sir Isaac Newton suggested the road locomotive shown in the accompanying illustration. It consists of a spherical steam generator *B* under which is a fire-grate *D*, the whole mounted on a carriage. A long nozzle *C* projects from the generator in a rearward direction.

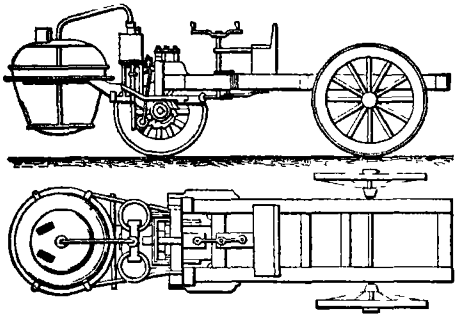


SIR ISAAC NEWTON'S STEAM CARRIAGE (1680)

The steam issuing from this nozzle at great velocity will react upon the air, thus driving the vehicle forward. The valve *F*, which admits steam to the nozzle, is under control of the driver through the lever *E*. We have no record showing that Newton ever built such a machine, though the idea, while crude, is feasible.

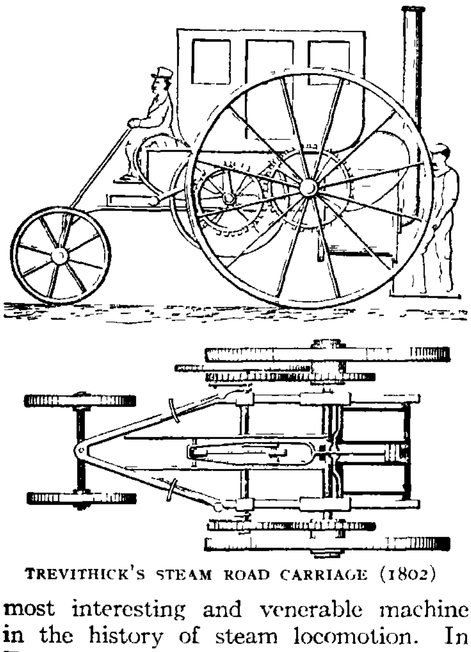
The invention of the steam engine near the end of the eighteenth century naturally revived speculations as to the possibilities of flying and of power-driven vehicles, and many interesting and curious suggestions were made bearing upon these problems. An English linen draper named Francis Moore invented a self-propelled vehicle in 1769 and was so sure of its success that he and many of his friends sold their horses. Watt himself was not very enthusiastic over the use of the steam engine for vehicles and appears to have discouraged it.

Out of the period of speculation and experiment there emerged in 1769 the first steam locomotive engine that actually carried passengers. It was the invention of a Frenchman, Nicholas Cugnot. On



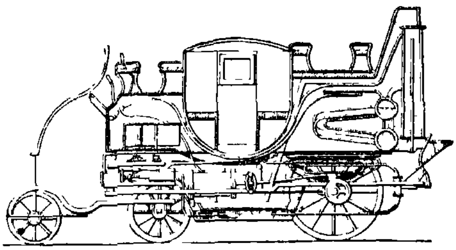
CUGNOT'S SECOND STEAM WAGON (1770)

its first run it carried four persons at the rate of two and a quarter miles an hour. Cugnot was immediately commissioned by the French government to build an improved and more powerful machine that would draw cannon. This second machine is still preserved and is, without doubt, the



TREVITHICK'S STEAM ROAD CARRIAGE (1802)

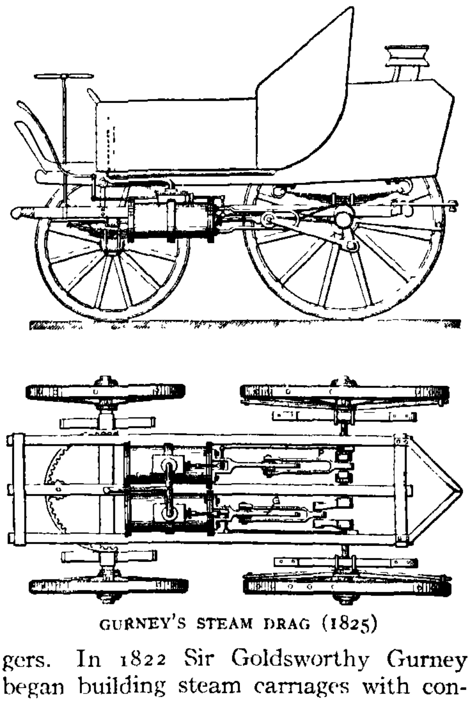
most interesting and venerable machine in the history of steam locomotion. In England, William Murdock, one of Watt's assistants, produced a small steam road locomotive in 1784, which is said to have traveled 6 to 8 miles an hour, and Trevithick, who afterwards became famous by constructing the first successful locomotive running on rails, built a successful steam carriage in 1802. In America Oliver



GURNEY'S STEAM CARRIAGE (1822)

Evans built in 1804 his "Orukutor Amphibolis" which traveled on both land and water.

These attempts were all more or less experimental, but in 1829 W. H. James operated successfully a road coach that ran 15 miles an hour and carried passen-



GURNEY'S STEAM DRAG (1825)

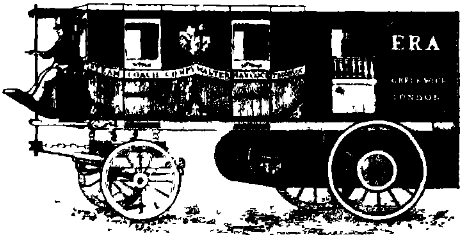
gers. In 1822 Sir Goldsworthy Gurney began building steam carriages with considerable success. One of his coaches is shown in the illustrations, and it will be noticed that the boiler, which is fixed on

the rear of the machine, was built up of tubes and was quite a highly developed affair. Perhaps the most successful of the early builders of steam carriages was Walter Hancock of Stratford, London. Hancock invented an ingenious boiler which could withstand high pressures and which was quite compact. In 1834, from August to November, Hancock operated his two steam carriages, the "Era" and the "Autopsy," between London and Paddington, carrying all together nearly 4000 passengers and running at a speed of twelve miles an hour. Alexander Gordon, writing in 1832, records boilers for road locomotives that carried working pressures as high as 200 pounds to the square inch and engines that gave as high as twenty horse-power, constructed for this service. He also describes crude condensers for condensing the steam after it had been used in the engine of the road locomotive so that it could be returned to the boiler, thus anticipating the more highly developed engines of later days. Coke was used as a fuel almost exclusively.

Early opposition to motor traffic by road owners and users

The problem of road locomotion by power vehicles seemed in a fair way to be solved when inventors and promoters of these machines were confronted by a form of opposition that almost always appears when new and radical improvements are proposed. Road owners and those who used the roads, farmers, coachmen and coach proprietors all joined in a strong opposition to the new vehicles. Some said they were exceedingly dangerous, that they frightened the horses, and others that they ruined the roads. Those interested in stage coaches of course objected to them because if they were successful the coach business would be ruined. One of the engineers engaged in operating one of the early steam coaches writes: "We are surrounded with prejudiced people — agriculturists, coach proprietors, coachmen, stable-boys and others directly or indirectly connected with them: these with the old ladies of Cheltenham, I assure you, offer a formidable opposition to any innovation."

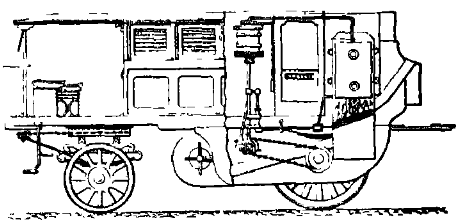
Although the promoters of steam coaches proved that they were an economical gain; that the land used to support one horse would support eight people and that there were 2,000,000 horses in the kingdom, many laws were passed restricting the use



HANCOCK'S STEAM CARRIAGE "ERA" (1834)

of steam-driven vehicles and taxing them very heavily as compared to horse-drawn coaches.

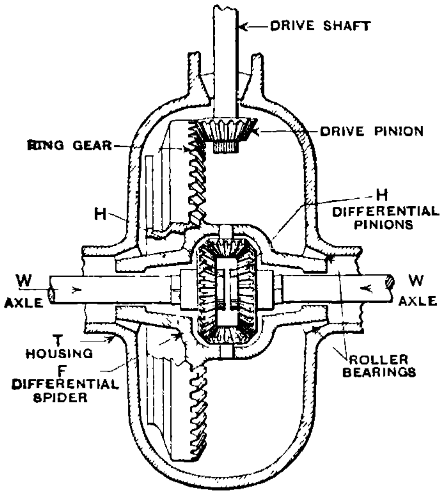
Some of the promoters of the new machines became discouraged and others turned their attention to the development of steam railways, the story of which is told elsewhere in these volumes. Interest in the steam carriage as a means of transporting passengers over the road has never died entirely and has been revived from time to time in later years. For the most part, however, the successful application of steam to road locomotives has been confined to heavy traction machines, road rollers and similar apparatus. The remarkable success of the railway and the rapid development of railroads did much, no doubt, to hold back the development of the steam road carriage. We have no assurance, however, that even though these



HANCOCK'S STEAM OMNIBUS (1839)

drawbacks had not existed the steam coach would have been a marked success. We are indebted, however, to the pioneers in this field for a few inventions that are still much used in automobile construction.

Until Hancock's time the spokes of wheeled vehicles were hammered into a central wooden hub, as may still be seen in ordinary carts. Hancock found that wheels so made would not stand axle-drive without the spokes breaking. He therefore made the inner ends of his spokes wedge-shaped so that they fitted closely together at these ends and clamped them between two iron discs one of which carried a hub or boss that fitted the axle. One of these carried a pair of projecting lugs which engaged with a corresponding pair that were made fast to the axle and revolved with it. This arrangement gave



PRINCIPLE OF THE DIFFERENTIAL GEAR

a little flexibility in the connection between the wheel and the axle. Practically all wooden automobile wheels are still made in this manner.

Another important improvement was the compensating or "differential gear" introduced by F. Hill, but invented by Richard Roberts. It will be noted that when a cart or car goes around a curve the wheel on the outer side of the curve must travel farther than that on the inner side. If both wheels are made fast to the axle, there must be a certain amount of slipping between the wheels and the ground, and if the car is moving at high speed, especially over a wet surface, this action is not only unpleasant to the occupants but exceedingly dangerous as well.

In many of the early cars the wheels were driven independently or were connected to the driving shaft through clutches that could be thrown in and out at will.

Roberts' invention, which has become indispensable in automobile construction, has been improved into the modern differential gear, where the axle is in two parts, each part carrying a gear *H* and a wheel *W*. The tube *T* is fast to the body of the machine and does not rotate. The frame *F* is rotated by the engine and the wheels can move relatively to each other when traveling over paths of different lengths.

The construction of many of these early steam-driven cars was excellent both in theory and workmanship, and some of their performances are noteworthy as pioneer records. It is doubtful, however, if any great development would have ensued along these lines without several other improvements which were needed before the modern automobile could be finally evolved. Of these the most important is the gasoline engine and, of secondary importance, the pneumatic tire and ball and roller bearings, which have contributed in no small degree to the success of the vehicle. The ball bearing and the pneumatic tire were perfected in connection with the bicycle.

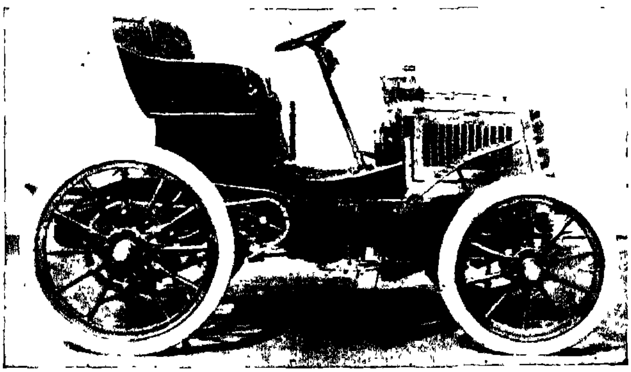
The application of the gasoline engine to road transportation

The modern gas engine was invented in 1860 and was made a commercial possibility by Otto in 1878. The theory and general construction of gas and gasoline engines is explained in other chapters of this section. The gasoline engines that are used in automobiles operate on the Beau de Rochas or Otto "four-cycle" plan. They have a distinct external appearance, however, because they have been adapted to fill a peculiar want. The invention of the new motor gave at once a great impetus to the study of the horseless carriage. In 1884 Gottlieb Daimler, a German inventor, produced and patented a small high-speed gas engine which was very light for the power that it developed.

Ignition was obtained by a hot tube aided by the heat of compression. This was followed in 1885 by a patent on the inclosed crank type of motor which became famous in the history of automobile construction. In the same year Daimler patented an application of his engine to bicycles, thus giving the first suggestion of the use of the new motor for road carriages. For this machine he devised the first carburetor for volatilizing gasoline or spirits so that it could be burned in a gas engine.

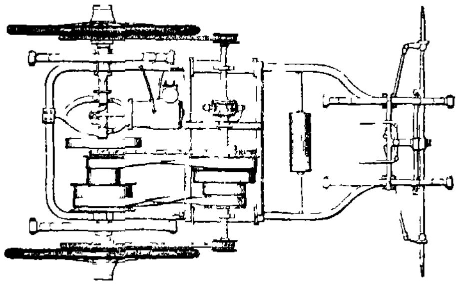
After numerous experiments Daimler patented in 1889 a double inclined engine which proved very successful in connection with automobiles. This engine was known as the "V" type and some of the best airplane and automobile engines are now made in this form, like the famous Liberty motors, though, of course, they are very highly developed machines when compared to Daimler's original engine.

In 1886 Carl Benz of Mannheim, Germany, patented a tricycle driven by a gasoline engine. His cars proved so successful that many were manufactured and Benz is looked upon as one of the great pioneers in this industry. The success of Daimler and Benz naturally stimulated experimentation and many inventors soon appeared. Among these several Frenchmen, such as Serpollet, Peugot, Panhard, Levassor, De Dion Bouton and others, contributed much to perfect the mechanism of the new form of road carriage. The enthusiasm spread quickly to England and America. The Duryeas built their first motor vehicle in the United States in 1891 and by the beginning of the twentieth century the gasoline-driven road carriage had been developed to the point where it was an assured success.



12-HORSE-POWER PANHARD, 1898 MODEL

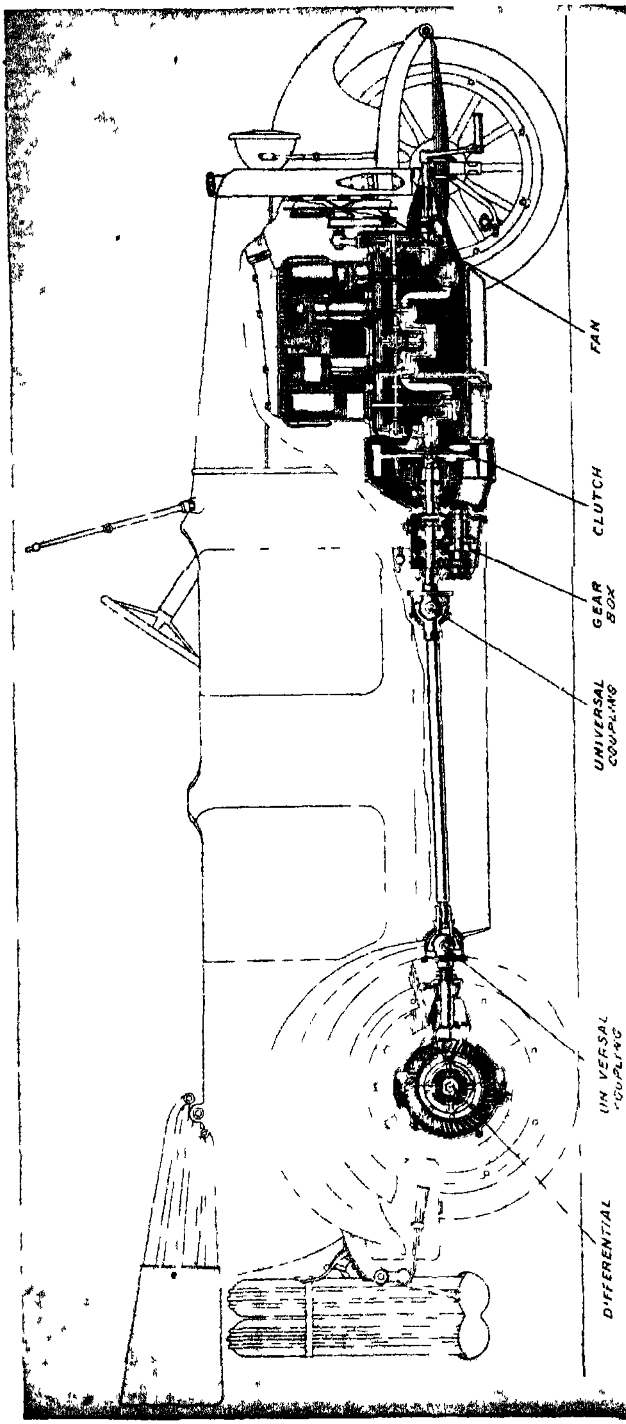
The conception of these pioneers of how an automobile should be constructed was far removed from the familiar machine of today. They naturally thought of a carriage like the horse-drawn vehicles of their day with a motor instead of a horse, and even as late as 1900 this idea still survived.



PLAN OF MUELLER (BENZ) TRAP

By 1900, however, the main features of the modern machine began to emerge from this chaotic state. The engine appears in front of the driver on top of the frame, the wheels are lower and pneumatic tires are universal. The dashboard of the old horse-driven carriage begins to disappear. The engine is still geared to the driving axle through a chain, but this soon gives way to the modern direct drive, and the many improvements and refinements that have made the automobile so reliable and easy to handle now begin to appear in rapid succession.

So long as any piece of apparatus is in process of growth and change it is not economically possible to manufacture it in large quantities, because it does not pay to make the special tools and fixtures that are necessary for mass production. While the automobile was in the experimental stage and during the period of rapid development, the manufacturing operations were performed largely by hand.

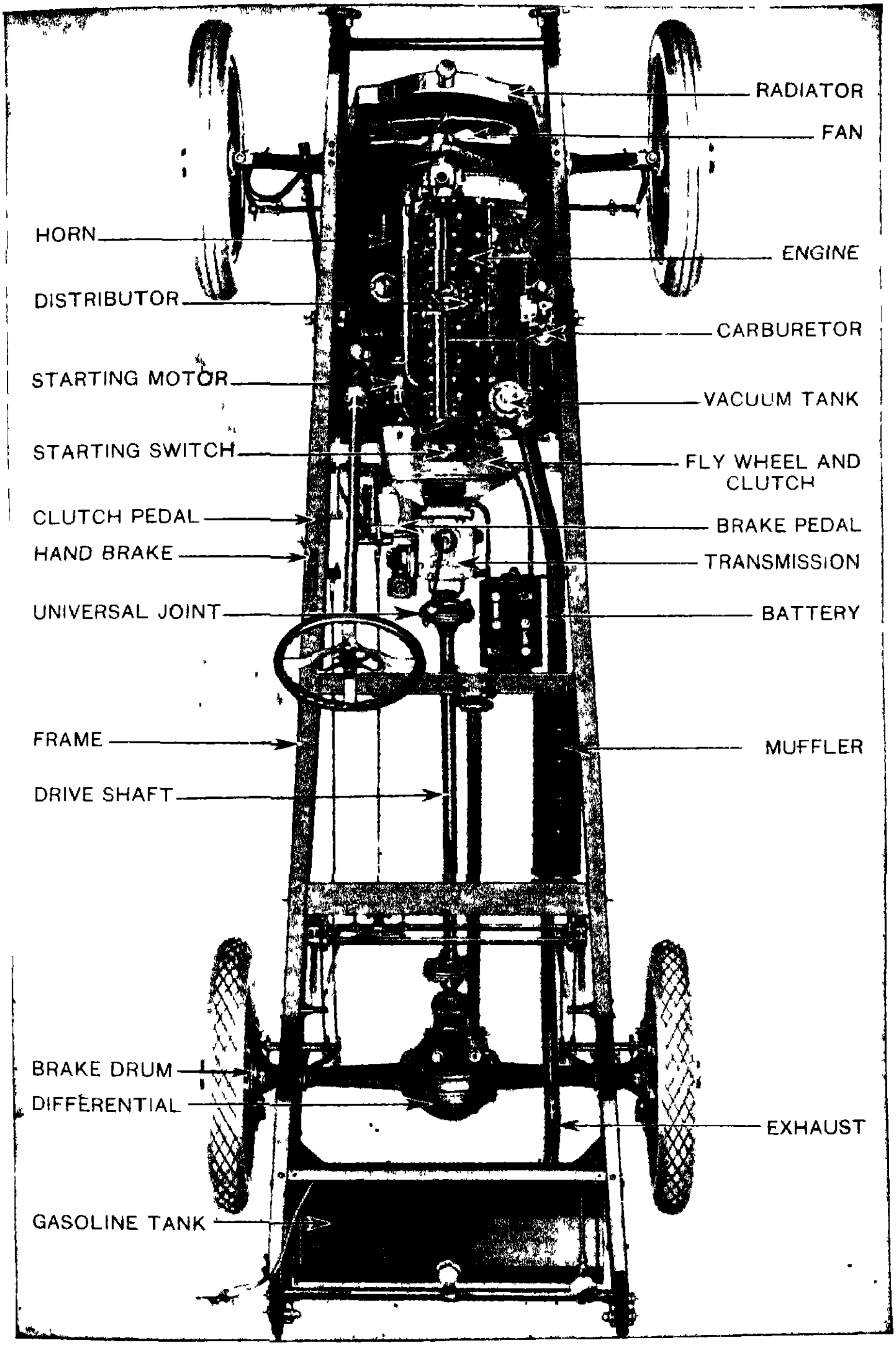


Court... SIDE VIEW OF A MODERN AUTOMOBILE SHOWING THE IMPORTANT PARTS AND HOW THEY ARE CONNECTED

A few years ago, however, it became apparent that the general form of the automobile had become stabilized sufficiently to warrant production in large quantities with the consequent reduction in price and increase in number of purchasers.

Before examining the methods and processes by which this great output is obtained, it will be helpful to look at the principal features of a typical modern automobile. In the accompanying illustration there is shown a plan view of an automobile with the body which carries the seats removed. The principal parts are named. It will be seen that the frame which is of pressed steel is attached to the axles through heavy springs. The front axle is not pivoted on the frame, but the front wheels are knuckled on the axle so that they can be turned by the steering gear and thus change the direction of the automobile. The engine is made in one unit and is fastened to the forward end of the frame. The rear end of the engine casing is enlarged so as to completely inclose the flywheel and in this same casing is placed the clutch through which the operator can connect and disconnect the engine and the transmission gear at will. The engine can therefore be kept running even when the car is standing still, an obvious advantage in traffic

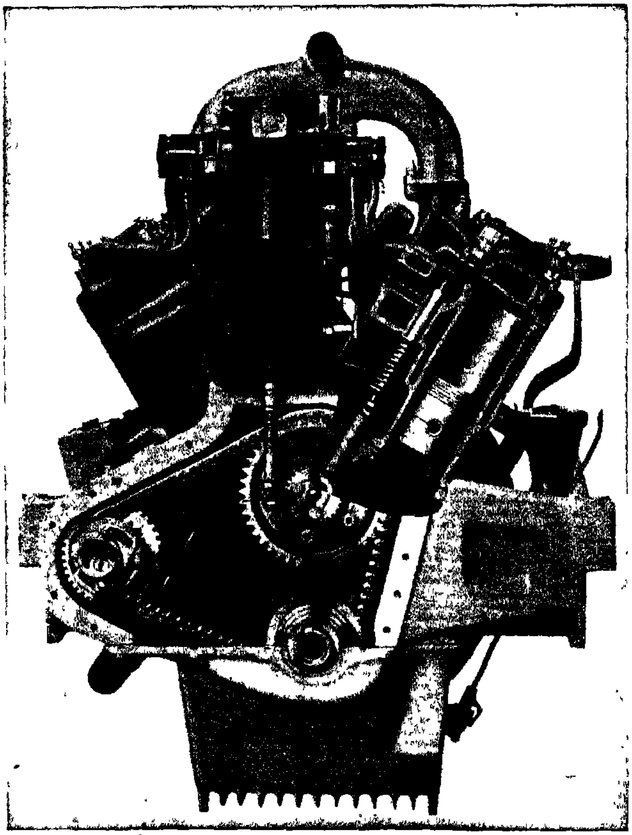
ESSENTIAL PARTS OF THE CHASSIS



PLAN OF CHASSIS SHOWING RELATION OF ESSENTIAL PARTS

Next to the clutch, and usually inclosed, also, in an extension of the engine casing, is the gear-box. This is a device for changing the relative speed of the driving shaft and for reversing the direction of its motion. In steam-driven cars no gear-box is necessary, as the steam engine can be readily reversed and is much more flexible in the matter of speed control. It has been found by experience that it is better to keep the automobile gas engine running in the same direction and to obtain the reverse motion by gearing. The gear-box also provides several changes of speed by bringing different combinations of gears into operation.

The engine usually is placed in a horizontal position and in order that the main shaft may connect properly with the rear axle it must make an angle with the engine shaft. To permit this a "flexible joint" or "universal coupling" is placed between the gear-box and the driving shaft and connects them together. The shaft is completely inclosed in a metal casing which connects with a similar casing which covers the rear axle. This latter casing is enlarged in the center so as to inclose the differential gear which connects the main shaft to the rear axles.



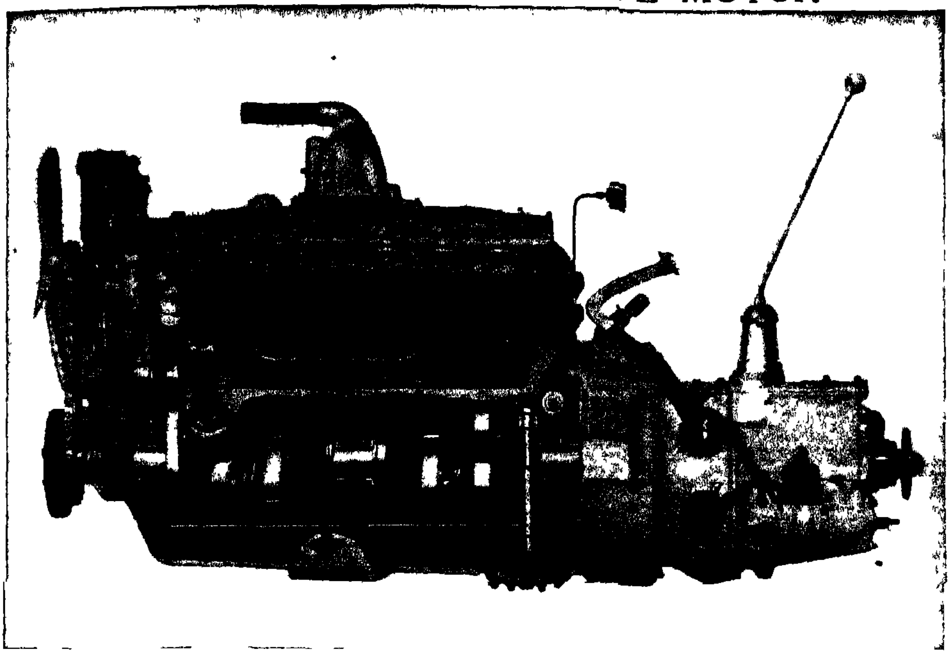
Courtesy Packard Motor Co

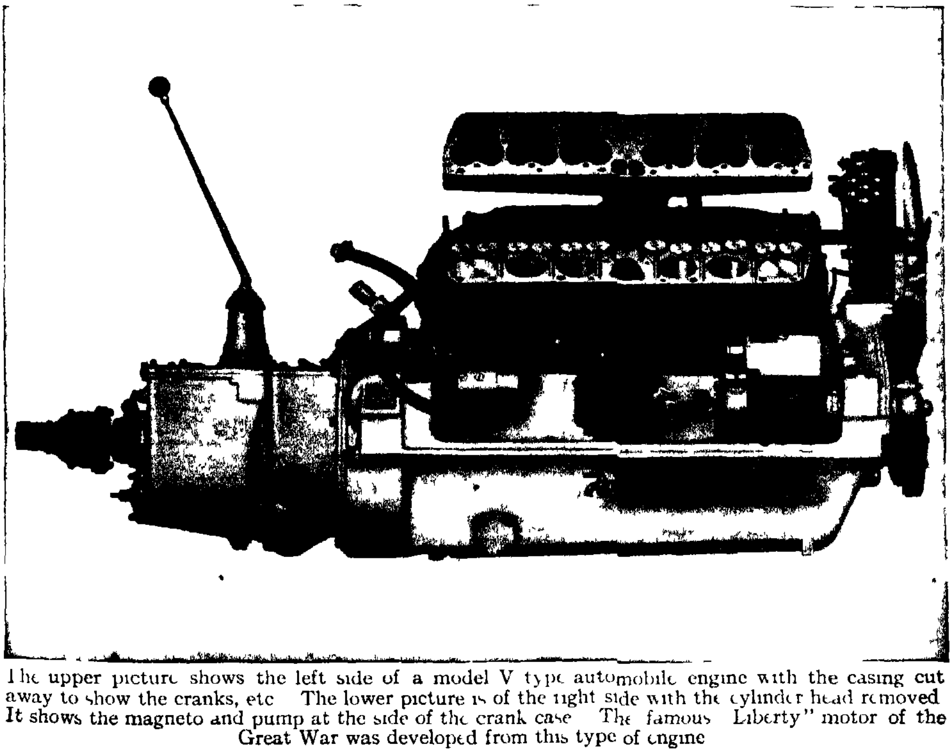
END VIEW OF A TYPICAL V MODEL ENGINE WITH A SECTIONAL VIEW OF ONE OF THE CYLINDERS

The chain drives the auxiliary shafts which time the spark and operate the magneto and pump

A small auxiliary shaft driven from the main engine shaft runs a little rotary pump which circulates the water through the water jackets of the cylinder, where it absorbs some of the heat of the explosions, and thence to the large surface radiator, where it is cooled by the action of the air forced through the radiator by the motion of the car. This action is usually accelerated by a small fan driven off the engine shaft. The pump shaft also drives the magneto for furnishing the electric spark which explodes the gas in the cylinders. Most modern cars carry an electric storage battery which not only furnishes light for the several lamps, but also operates a small motor for starting the car. This motor can be connected at will by the operator. In some automobiles the current for ignition is furnished by an electric generator large enough to keep the battery charged to full voltage, and in others the starting motor has a second winding so that it acts also as an electric generator for restoring the voltage of the battery. These electric relations between the battery and the generator and the motor are self-adjusting and require no care on the part of the operator.

TWO VIEWS OF A V TYPE MOTOR





The upper picture shows the left side of a model V type automobile engine with the casing cut away to show the cranks, etc The lower picture is of the right side with the cylinder head removed It shows the magneto and pump at the side of the crank case The famous Liberty" motor of the Great War was developed from this type of engine

An automobile consists of from 3000 to 4000 distinct pieces, but it will be noted that these many pieces are assembled into units that can be put together as such before being incorporated into the completed machine. Thus the engine and its pump, magneto and other attachments make one unit. The gear-box, radiator, steering mechanism, differential gear, the springs and the frame can all be constructed as independent units and then assembled

MULTIPLE-SPINDLE DRILL
Drilling 81 holes simultaneously in the crank case of the Willys-Overland engine

into the finished automobile. It may be helpful to look a little more closely at some of these more important units before discussing the methods by which they are produced.

The motive power in the modern automobile is a multi-cylinder gasoline engine operating on the Otto or four-cycle principle that is described in the chapter on oil engines. There are not less than four cylinders and sometimes there are as many as twelve.

Where more than six are employed they are usually arranged in V form, as Daimler did in some of his early engines. The principal advantage in having several cylinders is in securing a more uniform turning action on the crank shaft and hence a smoother operation of the engine. Each cylinder has an inlet and an exhaust valve operated from a cam shaft which lies parallel to the crank shaft. The general principles of automobile engines are much the same, though the details differ widely in different makes of cars.

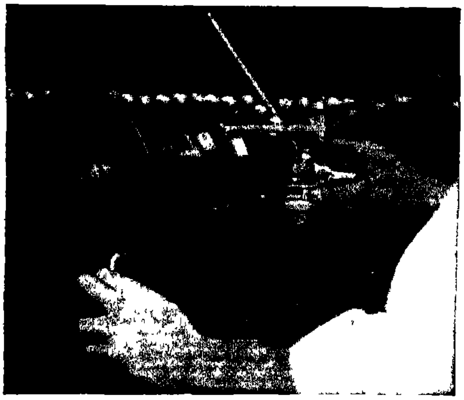
Automobiles are now produced by what are called "mass production" methods. When only a few machines of a given kind are to be produced, the several parts may be assembled, fitted to each other, and much hand-fitting and adjusting done by the same workmen. But where a great number of parts is involved, and the factory covers a very large area, such methods cannot be used because they require too much transportation. In such a case every part is made exactly to the required size and no fitting or filing is necessary or permitted when the parts are assembled. Such a procedure requires very exact tools and methods and very careful inspection with standard gauges and other measuring devices at the time the parts are made. A special "tool department" is charged with the task of making and keeping in order all tools and fixtures, and an "inspection department" is charged with the task of seeing to it that no parts go to the assembly that are not up to standard size and quality.

The accuracy required varies, of course, with the various parts. The Cadillac Motor Company states that in one of their cars over 1000 operations are performed to within one-thousandth of an inch of the nominal required size, and that 300 operations are performed to within the one-half thousandth of an inch of the nominal size. Modern measuring standards are made accurate to the one hundred-thousandth part of an inch and there is no great difficulty with proper tools in making independently large numbers of parts that will fit together accurately when assembled into a completed machine.

A TYPICAL MACHINE FLOOR IN A GREAT AUTOMOBILE FACTORY

THIS PICTURE SHOWS THE CRANK SHAFT DEPARTMENT OF THE FORD MOTOR CO.

No automobile factory produces the complete machine within its own shops, but all depend more or less upon other factories that manufacture certain parts for the trade. These are sometimes furnished in the rough or they may come completely finished ready to bolt into place. Thus most automobile builders buy their wheels, but the ball or roller bearings that are used in them have in turn been bought from specialists in that line. Axles are usually furnished in the rough, though these again may come completely finished, or may have been forged in the factory itself. The making of bodies is a large business by itself, and most automobile builders buy their bodies, though they upholster them



INSPECTING CAM-SHAFTS AT THE WILLYS-OVERLAND FACTORY

in their own factory. The magneto or generator, the storage battery, and the self-starting and lighting systems are usually purchased from some specialist who makes them to fit the particular automobile for which they are intended. The small instruments such as carburetors, voltmeters, speedometers, and other refinements are always purchased from other manufacturers who specialize in them. Then again there are many things, such as bolts and nuts, washers and innumerable small parts, that may or may not be purchased depending on the size of the factory and the nature of the product.

There has grown up, therefore, an immense business in automobile accessories and hundreds of large factories are devoting all of their energies to making these parts, although their name is never heard in connection with any particular automobile. Few lines of production have such a widespread ramification. The remarkable system of interchangeable parts, through the use of the delicate and accurate measuring devices that have been mentioned, makes it possible for a manufacturer of starting systems in Dayton to make such pieces of apparatus by thousands that will fit perfectly into cars made in Detroit.

This same idea is carried out within the automobile factory itself. There are, of course, departments that are somewhat general in character. Thus the foundry will make all cast-iron parts necessary. The screw-machine department will manufacture all bolts and screws that are made by the factory, as well as many small circular parts of varied form. But, in general, each department is a "single-purpose" one, devoting itself to a small range of work, possibly producing only a single part.

Here, for instance, is a very large department that is devoted to grinding the bearings on the crank shaft; another is occupied entirely with finishing the pistons for the cylinders, while still another performs all the machining of the cylinders. Many of these great rooms are equipped with special machinery of interesting and complex construction, designed solely for the work of that department. Each cylinder casting, for instance, must have many holes drilled into it for the several bolts and fastenings. In small manufacturing these would be drilled on a simple drilling machine one at a time. But in mass production of this kind the cylinder is put into an iron casing into which it fits exactly. The outside of the casing is pierced with holes which locate the holes that are to be drilled. These locating holes are surrounded with hardened steel "bushings" or guiding rings. This casing, or "drilling fixture" as it is called, is pushed into a machine in correct position, drills move forward simultaneously from several sides, pass into the guiding bushings, and drill the holes to the correct depth and in just the right place.

MASS PRODUCTION AT TWO FACTORIES

PRESS ROOM OF THE DODGE MOTOR CO

Here many of the different parts are shaped as required from cold steel under gigantic pressure

UNIT PROGRESSIVE ASSEMBLY

On the chain carriers may be seen Ford engine parts moving along to receive in turn the others which go to make up the complete engine — a most interesting example of quantity production

No skill of hand is needed, and the entire operation occupies less time than would be consumed in making one hole in the usual way. In one particular case of this kind eighty-one holes are drilled at the same time. It is by methods such as this that vast production is secured at a minimum cost of labor.

The thousands of individual parts that pass through the special machinery departments all flow to the particular unit assembly department to which they belong. Thus all cylinders, pistons, cylinder heads, connecting rods and everything else pertaining to the cylinder are directed to the motor assembly department where the power unit is assembled before placing it in the car. Assembling can be conducted in two ways. Where only a very small number of units is to be assembled it is customary and usually most economical to locate permanently the main member of the machine and to carry to it all of the auxiliary parts to complete it. In such assembly one set of men often does all the work on each machine.

In mass production, however, "progressive assembly" is becoming common and the automobile builders have done much to advance this most economical of methods. In assembling motors by this method the cylinders, which are the main part of the motor, are placed upon a long moving carrier. The several auxiliary parts are supplied at proper places and in proper sequence and attached by different groups of men, who stand along the side of the carrier, each group and each individual of each group performing a fixed, given task, so that when the cylinder reaches the end of the carrier the motor is complete.

This form of assembly permits more frequent and hence accurate inspection than when the work is all performed by a few men. The motor goes from the assembly carrier to the test floor. Here it is mounted on a special frame so that it can be driven by an electric motor and thoroughly limbered up. It is then tested under its own power and carefully inspected, before being passed upon as ready for the final assembly of the automobile.

The final progressive assembly of the car the most spectacular

This is conducted in a similar manner, but is far more interesting and spectacular. At the starting end of the long carrier a front axle unit and a rear axle unit are each assembled on a frame unit and the combination is started down the carrier. These carriers are sometimes over 600 feet long and they move at the rate of about six feet per minute. As there are many cars moving along at the same time, as high as 300 cars have been assembled in the Ford plant on one carrier in eight hours' time. The speed of the carriers in the unit assemblies varies with the product and may be as low as four feet per minute.

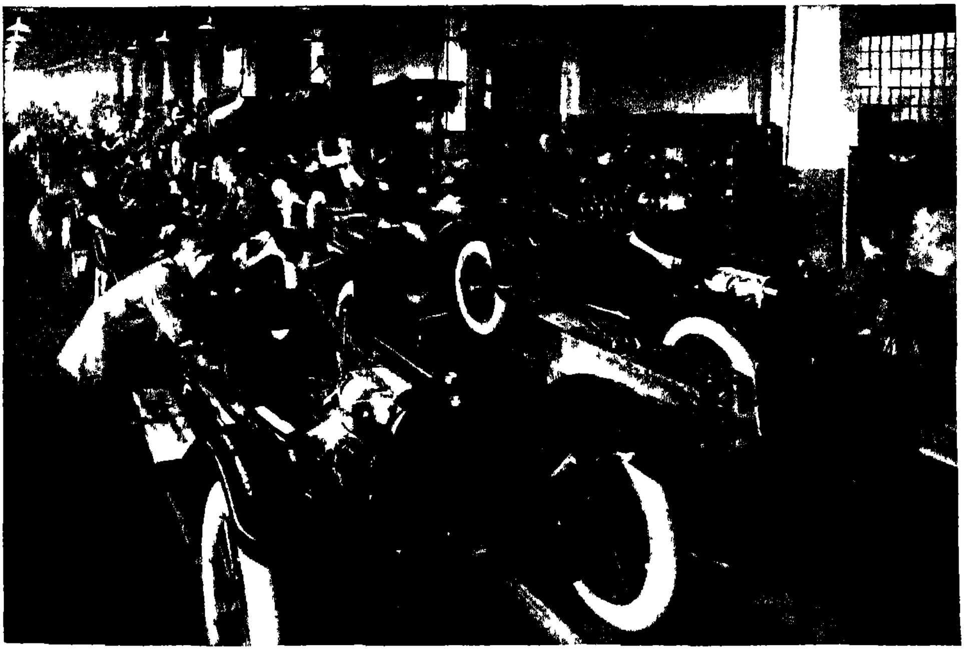
As the frame moves along the carrier, successive groups of workmen attach the springs, wheels, mud-guards, steering gear, engine, gasoline tank, dash, radiator and body all in a prearranged and logical sequence. The many small operations incident to complete assembly, even to the putting of gasoline in the tank and oiling all of the bearings, are carried out successively as the frame moves along, until as it nears the end of the carrier it has become an automobile. Some of the unit parts are supplied by overhead carriers, some come down chutes from upper floors, but all arrive at the exact place where they are needed and in such quantity that there is no waiting for parts.

At the end of the carrier the rear wheels engage with a pair of large grooved wheels which project from the floor. These grooved wheels are driven by an electric motor and through them the rear wheels of the car are set revolving and the entire chain of mechanism going, to make sure that everything is correctly coupled and in running order. The car is then started under its own power and moves away from the carrier. It is almost startling to see the sureness with which these new cars start off; rarely do they refuse to function at the first attempt. The car is then again thoroughly inspected and, if found to be all right, is taken out to be tested before shipment. This usually includes an actual test upon the road.

FINAL PROGRESSIVE ASSEMBLY

FINAL PROGRESSIVE ASSEMBLY OF THE FORD

The chassis frame is placed upon a carrier and the parts added by successive workmen as it reaches them. When it arrives at the delivery end it is a complete car, ready for the road



DELIVERY END OF THE PROGRESSIVE ASSEMBLY

Here are the workmen putting the finishing touches to a Dodge. A car complete, ready for the road, is seen on the right-hand carrier.

How all the materials are tested so as to get only the very best

Some of the larger manufacturers do not assemble all of their cars at the factory, but ship the parts to district centers where they are assembled. There are manifest advantages in this procedure, as it is much more economical to ship the parts than the completed car. High-grade cars are more likely to be completed and tested at the factory.

Not the least important feature of automobile construction is the care taken to secure the highest quality of material. This is true of the cheap as well as the higher-priced car. Automobile builders, in fact, have been among the foremost in developing special alloys of steel that will combine maximum strength and toughness with extreme lightness. It is for this reason that automobiles, in general, will stand so much hard work over rough roads. There are few machines built today that have had the advantage of such a careful study of the materials that go into their construction. This study covers not only the constituents that enter into the metal parts, but also includes special methods of heating and tempering these parts so as to obtain the best structure possible with a given kind of metal. "Heat treatment," so-called, is applied to all important steel parts with these ends in view. Every up-to-date automobile factory also maintains a good metallurgical and testing laboratory where materials of all kinds can be tested for quality, strength and durability, so as to secure the best that can be had, or the best for a given price.

The rise of the automobile is the most spectacular thing in the history of modern industry. Most of the well-known American automobile builders have been in business less than twenty years and some of their plants, like Ford, General Motors, Studebaker and others, have already reached gigantic proportions. The number of persons engaged in the industry has risen from 13,333 in 1904 to 2,893,563 in 1924, and the capital invested from less than six million to more than two billion dollars.

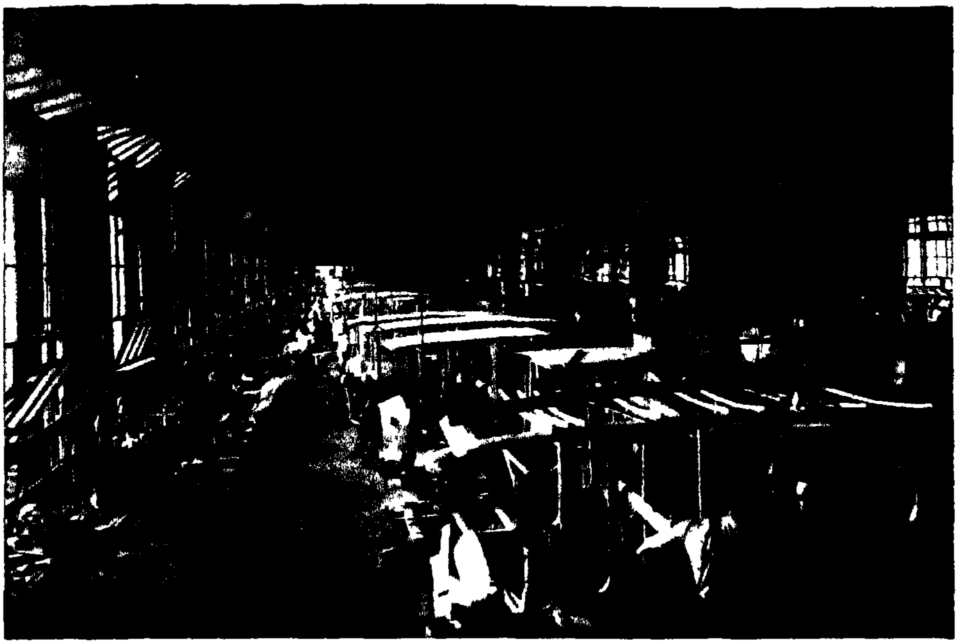
Of course, as is natural, the plants that build the high-priced cars are not so large, but still they are big factories even in these days of mammoth institutions. The capital investment in these great enterprises is staggering, and when one considers the auxiliary industries that depend upon them, the wonder grows as to where the cars go and where the wealth comes from to purchase them. It is estimated that 3,380,253 passenger motor vehicles and 444,884 motor trucks were made in this country and Canada in 1925, and that the value of this product was over two billion, two hundred and thirty million dollars. The total number of automobiles registered in the United States in 1924 was 17,591,981, or one car to every 6 persons, and the rate of increase does not appear to lessen in spite of the high cost of gasoline.

Number of horses said to be increasing in spite of automobiles

It is often stated that the automobile would in time cause the horse to disappear. So far this prophecy has not been fulfilled, and Mr. G. Arthur Bell of the Bureau of Animal Industry is quoted as stating that the number of horses in the United States has increased five per cent since 1910 in spite of the great increase in the number of automobiles. It would appear that the need of the horse in rural occupations and similar work increases faster than the automobile can displace him.

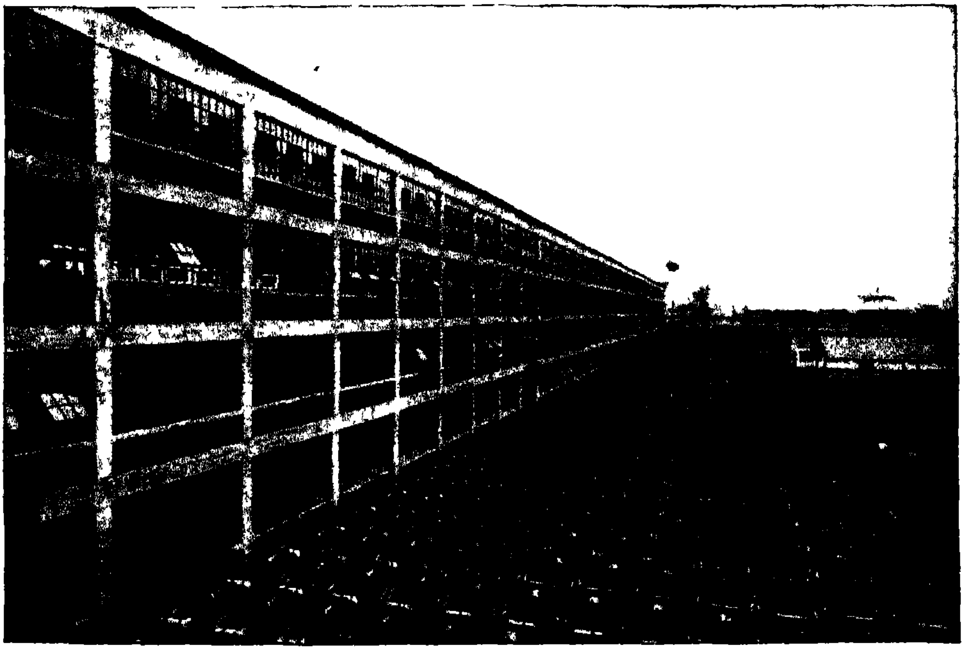
A more important and interesting speculation concerns the future of the automobile. It is apparent that the supply of petroleum will soon be exhausted, and even now gasoline is becoming expensive. New and advanced methods of production may add to our supply somewhat, but unless new oil fields are discovered the end of this commodity is not far off. We must look elsewhere for fuel for automobiles. Distillates from vegetable products can be made that will work well in gas engines and the hope of the future appears to lie in this direction. Let us hope that some scientist will soon come to our rescue and that we shall not lose the services of this, the most luxurious and pleasing mode of land transportation man has ever known.

GETTING THE BODY READY FOR THE CHASSIS



BODY DEPARTMENT OF THE PIERCE ARROW CO

Many automobile manufacturers buy their bodies from specialists who devote themselves solely to that branch of industry. Not so the Pierce Arrow.



ONE DAY'S OUTPUT AT THE FORD PLANT

This picture was taken some time ago and shows 1000 complete chassis as a day's output at the Detroit plant. *Since then over three times as many have been turned out in one day there.*

WAR, THE MAKER OF WIDOWS AND ORPHANS

"THE FOOTPRINTS OF WAR"—FROM F. W. LAWSON'S PICTURE IN THE LIVERPOOL ART GALLERY

War is one of the factors in the problem of the over-balance of the sexes. It has been estimated that the recent Great War cost Europe the lives of ten million men, and in striking down the father and the bread-winner war destroys the natural means of carrying on the race.

OUR MINORITY OF WOMEN

In Europe It Is the Men Who Are in the Minority. The Natural Balance Between the Sexes

IS IT POSSIBLE TO ARTIFICIALLY DETERMINE SEX?

FEW things have a more important bearing on the general position of human affairs than the relative numbers of men and women. At the present time, there are in the nations of western Europe many more females than males, and some men of science think that out of this fact arise many of the social problems which confront those societies. On the other hand, the nations peopled by European settlers in the New World and in the islands of the Pacific show a notable excess of males, and it is possible that some of the prominent characteristics of these countries are traceable to this fact. It may be, for example, that the higher standing of woman and the greater deference shown her in our country and in Australia, especially the readiness to accord her political power, is due in part to a sort of law of supply and demand, to the relative scarcity of women as compared with an actual overabundance in European countries.

One thing is clear, the excess of females in European nations is not due to war. It is greatest in England, which before the Great War had over one million more females than males, although at that time it had not been seriously affected by war since the downfall of Napoleon. Hence we must reject the views of the older school of thinkers who held that war was the chief factor in disturbing the balance of the sexes.

To reach a satisfactory explanation of this strange fact is difficult, because our sources of information are limited. In only a few countries are censuses taken and records of births, deaths, and migrations kept with sufficient detail and accuracy to show the relative numbers of the sexes at various ages and the causes of changes in the proportions. We are thus confined in our study of the problem of the proportions of the sexes to the statistics of the European races and to those regions in Europe or countries settled by Europeans whose governments publish the needed information. The principal fact which challenges explanation is that in Europe as a whole there are about one hundred and five male children born for every one hundred females, and yet in the population of Europe there are only about ninety-four males to one hundred females. In some countries the contrast is greater still. The following table shows the facts for some of them. The population figures relate to about the year 1920, while the birth-rates are averages for the four years from 1911 to 1914.

Country	Living Male Births per 100 Females	Males in Population per 100 Females
England and Wales	103.5	89.8
Belgium	103.3	97.1
France	104.1	96.4
Switzerland	105.1	93.1
German Empire	105.2	90.8
Russia	105.4	86.5
Italy	105.2	96.4
Austria	105.8	92.9
Hungary	104.3	94.2
Spain	105.7	94.1

These discrepancies are partly explained when we turn our attention to America and other countries settled by European emigration.

The greater migratoriness of men one of the disturbing factors

The figures for the proportions of the sexes in the United States afford a striking contrast to those for Europe, and suggest that the characteristic features of both may be accounted for by a greater movement of men than of women from Europe to the new European nations overseas. In the population of this country in 1920 there were 104 males to 100 females. It is interesting to look at the distribution of this excess of males among the different divisions of our population as classified by the census. Taking the native white population alone, the excess is very much smaller than for the total population, or 103 to 100, while in the foreign-born whites we find no fewer than 129 males for every 100 females. This difference agrees well with the immigration records, which show that from sixty to seventy per cent of the aliens coming to our shores are of the male sex.

The large shortage of men in England must be largely explained by emigration to the United States and the various British dominions. Thus, in Australia, there are more than 110 males to every 100 females, and in the newer states of the commonwealth the proportion is much greater, running up in Western Australia to nearly 160 to 100. Yet Australia, compared with the British colonies proper, has been largely peopled by persons emigrating with their families. The various dependencies call many men from the home country in various capacities, but very few women, and in the tropical colonies family life has not generally been found possible for white people.

Within a single country, again, particularly a large country like the United States, similar problems present themselves Seven of our older states now have a shortage of men, which is greatest in the District of Columbia, with 87 males to 100 females. On the other hand, in the states of the Far West, as a group, there were in 1910 more than 140 males to 100 females, and in one or two of those states nearly 2 to 1.

Within this country the frontier has now disappeared, and there is a rapid tendency toward an equilibrium, as far as the different sections of the country are concerned. During the ten years from 1910 to 1920 the ratio for the Western States fell from 140, as stated above, to less than 115 males per hundred females. This change was greatly accelerated by the war, however, which largely cut off immigration and caused a great many foreign-born men to return to their native countries for military and other service, in addition to the destruction of American male lives in the war itself. These include both the direct military losses and the increased deaths from disease in the camps. The effect is shown by the fall in the ratio of males to females in the country as a whole, which in 1910 had been 106 to 100 instead of 104.

Two other factors that contribute to the inequality in numbers of the sexes

But there are two other disturbing factors which have to be taken into account. The first is the movement of women to the cities, which, contrary to the popular impression, seems to be more rapid than that of men. It is also somewhat surprising that the attraction is mainly domestic service, and not factory work of any sort; this is proved by the sex-distribution of population within cities, and by a comparison of industrial and residential towns. The other factor mentioned is that of race. Two of the states with an excess of females are in the South, where, as compared with the North, rural conditions largely prevail, but where a large fraction of the population belongs to the black race. Unfortunately, we have few dependable birth statistics by race. It has been asserted that the excess of males at birth characteristic of the white race does not occur in the black. But it now seems more probable that the difference is rather in the greater effect upon the black race of the movement to the cities and of migration generally.

In no case, apparently, does migration explain all or nearly all the inequality of numbers of men and women.

The mysterious forces that control the balances between the sexes

It is a valid explanation as far as it goes; but in the United States, for example, it can account for only about two-fifths of the excess of males. Hence, for further light upon the problem we must carry the investigation into the field of biology. It is obvious that on the whole the proportions of the sexes must be determined by the relative numbers born and dying within a given period. Here we are struck by the strange fact that everywhere there are more boy babies born than girls, but that the boys apparently have weaker powers of resistance and die off faster, so that in the long run the balance would generally be nearly even but for the disturbing effect of migration. We have seen that the births of the sexes in European countries range about 105 males to 100 females. In the United States, as a whole, we do not have accurate registration of births and deaths, but for the states in which figures are available they are very similar to those for Europe. Thus for the same five years for which European figures were given in the table above, we find Connecticut showing 105.6 living male births to 100 female, and Massachusetts 106.4 to 100.

Let us now turn to the death-rates for the two sexes. In the registration area of the United States (exclusive of North Carolina) in 1910, the recorded death-rate of males was 16.0 per thousand per year, while for females it was 14.0 per thousand. These figures are none too dependable, and are subject to some definite corrections, such as that for the different age-distributions of the two sexes in the districts where the records were kept. A better indication of the relative longevity of male and female human beings is afforded by the following figures for two countries having very complete registration, and one of which (Bavaria) has a high general death-rate and the other (Sweden) a very low one. The numbers given are the percentages of those of the two sexes born alive who will live to the ages indicated.

PER CENT OF BOYS AND GIRLS BORN ALIVE WHO LIVE TO DIFFERENT AGES

Country and Sex	Per Cent Living at the Age of			
	1 Yr	20 Yrs	60 Yrs	80 Yrs.
Sweden				
Boys	90.7	81.7	56.6	19.3
Girls	92.4	83.1	60.4	22.7
Bavaria				
Boys . . .	75.1	67.2	41.1	7.4
Girls	79.2	70.8	46.6	9.6

It is readily seen that the girls and women have more vitality or are more tenacious of life than the boys and men. Careful study of the deaths by age shows that the relative mortality of the male sex is much higher in the early years, up to the age of five or ten, varying somewhat in different countries. Then there is a period of ten or fifteen years, up to about the age of twenty, when the death-rates are nearly equal, but that of the females is slightly higher. After this, again, there is a constantly growing discrepancy, to the disadvantage of the men.

A suggestion which at once presents itself is that the burdens of civilized life may rest more heavily on the shoulders of men than of women. This hypothesis receives some support when we contrast the countries of eastern and western Europe in respect to the proportions of the sexes. In those Balkan countries about which the facts are known, there are commonly more men than women, and the same is true in general of Eastern as opposed to Western civilizations. Now, in the East, women work as hard as men; they are equally exposed to the dangers of disease and the hardships of life, childbirth and maternity are more perilous than in the West, and they therefore succumb in about the same number, and the original proportion of the sexes is thus maintained.

On the other hand, this fact does not serve fully to explain the heavier mortality among male children which generally obtains throughout Europe. Up to the age of thirteen, boys and girls as a rule lead similarly sheltered lives.

Why the burden of making progress falls chiefly upon man

It is extravagant to suppose that boys receive from their mothers less care than girls, and the fact that fewer of them survive must be attributed to the more resistant powers of the female constitution.

No doubt men have more active strength than women. It has been calculated that the civilized woman is little more than half as powerful as the civilized man. Perhaps a considerable part of the difference in the bodily powers of the sexes can be attributed to persistent difference in training, but it is nevertheless clear that man has naturally more power than woman. Woman's blood is thinner and more watery than that of man. A man possesses on the average 5.2 million red corpuscles per cubic millimeter in his blood, while a woman has only 4.9 million corpuscles. There is no more conclusive evidence of an organic difference between man and woman than these tests of the blood. They show that man is better fitted for an active and strenuous life, and they afford an explanation for the curious fact that he is the instrument of progress. Man, as a rule, produces the variations in bodily structure and mental equipment on which the evolution of the race depends. On him falls the burden of striking out new paths. He is more unstable; goes farther backward and farther forward. Both idiocy and genius are commoner among men.

The woman who stores up energy and the man who lives on his capital

Men, in short, represent the progressive element in human life, and women the conservative element. A great difference in plant and animal life lies in the fact that the plant is concerned chiefly with storing energy, while the animal is occupied mainly in consuming it. The plant, by a very slow process, converts lifeless matter into vital substance, spending little energy and living at a profit. The animal is unable to change lifeless matter into vital substance, but it has developed powers of activity which enable it to prey on plants and other live things, and, in contrast with plant life, it lives at a loss of energy. Some men of science regard woman as the more plant-like and man as the more animal-like form of humanity. Woman has to store up energy for her function as a mother, while man lives, so to speak, on his capital. Man is by nature more active, more adventurous, more spendthrift of his powers, and this is probably why he dies in greater numbers. There is no need to put down the greater mortality among males entirely to that artificial instrument of selection which we call human warfare. Nature seems from the beginning to have made men muscularly stronger *yet more subject to disease and death* than are the mothers of the race. There is evidence that after a war, when the male population is reduced, there is a tendency for the proportion of male births to increase, thus working to restore the balance. This leads us to consider the problem of the forces which control sex. The mere fact of a consistent excess in the births of one sex is enough to show that it is not a matter of pure chance, as students of heredity were at first inclined to believe.

The possibility that sex may be subject to control through environment

It is easy to see how the advance of civilization may tend to increase the proportion of women by lightening the burdens thrown upon them, and decreasing the death-rate. At the same time, it is possible that modern life increases the physical and nervous strain upon men.

We now come to a remarkable theory which seems to indicate that the same result is brought about in a much more surprising fashion, through an indirect effect on the sex-distribution of births. At the same time, it may throw some light on the age-old problem of the artificial determination of sex.

In an ordinary way, a long and terrible war results in famine. As a consequence, the women of the race are not so well fed; and several famous men of science have shown that there is a connection between an abundance of nutrition and a preponderance of females, and between a scarcity of food and a preponderance of males.

THE TERROR OF FAMINE IN INDIA—FAMISHING PEASANTS APPEALING FOR RELIEF

An interesting theory of the forces controlling the proportions of the sexes suggests that it is partly a matter of nutriment, especially of the female parent There is some evidence that in times of famine or distress more boys are born than girls, which may help to restore the "balance" after a war.

The birth of boys in poor homes, and of girls among the well-to-do

The main facts in support of this theory are interesting. Furriers state that rich regions yield more furs from female animals, and poor regions more pelts from male animals. In mountainous regions, where life is hard and food scarce, more boys are born than in the neighboring lowlands. In Saxony, for instance, when the harvest is scanty, the birth rate of male children rises in proportion to the altitude of the country.

As a rule, more boys are born in rural than in urban districts, and it is reckoned that this is due to the fact that the diet of the people living in cities is richer, especially in meat, than the food of ordinary dwellers in the country. Then, in times of war, famine, and migration, more boys are also born, and it is generally agreed by men who have studied the subject that there are more boys in the poorer families than in the families of the well-to-do. It has been found throughout Europe that when the cost of living increases, the number of marriages diminishes. This decrease in marriage results in a decrease of the birth-rate, but a larger proportion of male children are born in these periods of general scarcity of food. With the recurrence of prosperity there is an increase in the number of marriages and births, and the proportion of female children rises.

TYPICAL TARTAR MEN

Were the Tartars impelled by an overbalance of the sexes?

When savage and barbaric peoples are perplexed by an inordinate disturbance of the balance of the sexes, they often resort to war, or strange and degrading marriage customs. A large increase in the male population seems naturally to lead to war, the young men are unable to get wives, and the chiefs and elders are at last compelled to find a vent for their energies by some act of aggression on neighboring tribes which results in battles. Up to recent times this was a constant source of war in southern Africa. Moreover, it is possible that a preponderance of young males among the Tartars gave rise to those wild, fierce, periodic explosions of force which disturbed the Mohammedan world, and swept over China on the one hand and Russia, on the other, and threatened to overwhelm Europe.

The Tartars lived originally, like the natives of Australia, in a parched and desert land, and their hardships probably made them a nation with an excess of men. They might have adopted polyandry like the modern Thibetans, but instead they took to warlike action. This is one theory to account for the fact that they have spread from China to Crimea, their very name meaning 'archer' or nomad and not referring to Hades. Many famous Russian men of genius are partly of Tartar descent.

Predominance of women is a suggested explanation of polygamy

On the other hand, it has been contended that the universal prevalence of polygamy in the nations of western Asia at the present time is due to an excess of women in the population. The famous traveler James Bruce, writing towards the end of the eighteenth century, claimed that he found from two to four women for each man in the region east and southeast of the Mediterranean. This region was once enormously fertile, and Bruce's statements would fit in with the theory that rich food tends to cause an excess of females.

However, some of Bruce's assertions have been proved to be erroneous, and it should be remembered that in general it is unsafe to build upon assertions in regard to population which are not based on a dependable census of the region. Similar theories have been advanced to explain both polygamy and female infanticide in China and India. But until definite information is available, such suggestions are at best but interesting speculations.

There has been accumulated a great mass of intricate and difficult scientific research on the subject of the determination of sex, but unfortunately no complete and definite experiment has yet been made. The deeper our men of science penetrate into this mystery of life, the more mysterious it becomes. It seems as though it will be long before we obtain the power over life possessed by certain insects. Bees and ants can perform miracles. By giving a larva a richer food than its companions they can transform it from a neutral worker into a great queen-mother. One man of science is inclined even to believe that bees can control the number of drones they wish to produce out of the eggs the queen lays. This has been much disputed, but other researches have shown facts as wonderful.

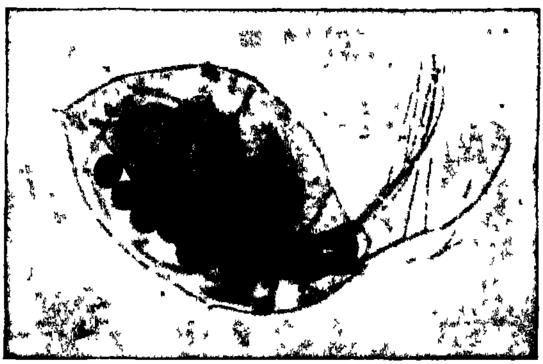
TYPES OF A WILD RACE THAT THREATENED EUROPE

The Tartars, of whom these are types, afford the most striking example of a people impelled to wild, fierce explosions of force by an over-balance of the sexes

The key to a great human problem, which may be found in a rose garden

Everybody who has a garden and tries to grow roses is sadly acquainted with the aphid, the insect which does great damage by feeding on rose bushes. In the summertime, when food is abundant, it gives birth entirely to female offspring, and only when the cold weather comes are some males born. There can be little doubt that it is not the change from summer to winter that determines the sex of these insects, but the amount of food the parent is able to obtain from the tree at the different seasons of the year.

This is made clear by another experiment made by Professor R. Hertwig, of Munich, who experimented with a tiny little creature, called a daphnia, which hops about ponds and rivers and swamps.



TINY CREATURE WITH KEY TO A GREAT PROBLEM

This little creature, called a daphnia, which spends its life hopping about ponds and swamps, gives birth only to female offspring in warm water, where food is plentiful, and only to male offspring in cold water, where food is poor

The daphnias were kept in various degrees of warm and cold water, because it was thought that temperature was the deciding factor. In each case those placed in ordinary warm water produced only a certain kind of female offspring, and it was discovered that this result was due to the fact that the warm water was *richer in food material* than the cold water.

It may be said that aphids and daphnias are a very low form of life, and that conclusions based on examining them do not apply to creatures higher in the scale. This objection has, indeed, often been made by men of high authority. But E. Young found that when tadpoles were reared under normal conditions the proportion of male to female was about as 43 to 57, but when a flesh diet was provided the percentage of females was greatly increased to 81. When we pass to higher animals, the difficulties of proving the influence of nutrition upon sex are much greater. Yet there are many observations which go to increase the cumulative evidence. Long ago an important experiment was made by Girou, who divided a flock of 300 ewes into equal parts, of which one-half were extremely well fed, while the others were kept on poor food. In the two cases the proportion of ewe lambs was respectively 60 and 40 per cent. Another observer, C. Düsing, has noted that it is the heavier ewes which usually bring forth ewe lambs.

Again, this evidence has been disputed, especially by the followers of Auguste Weismann, a Darwinian of the extreme school He will not admit that anything except the selection of the fittest has any influence in the evolution of life. This way of thinking, however, has now been overturned by researches made by students of both animals and plants. Men of science of the new school believe that life is more responsive to every kind of stimulus than Weismann fancied, and they hold that external influences more often mold the various forms of life than destroy all the variations and leave only one to flourish.

Under the influence of Weismann's theory, many men of science gave up the problem of the determination of sex, thinking that it was incapable of being solved; but now that theory is becoming modified, many new and enlightening researches are being undertaken. Professor Hertwig, of Munich, is the leader of the new school. He has attacked the most difficult of all problems — the problem of the cell — and he seems to be working his way toward a solution.

One of his pupils, S. Kowalewsky, has published a preliminary account of some investigations in regard to sex determination in animals. After reviewing all previous theories on the subject, Kowalewsky comes to the conclusion which we have maintained in this chapter. He holds that poor nutrition in the female parent is conducive to the production of male offspring, and that rich nutrition is conducive to the production of female offspring. In other words, an abundance of food and a good digestion enable a female parent to store up a great deal of energy, and this she hands on to the race by giving birth to a daughter. We have already seen that girls, in spite of their apparent weakness, have a more resistant constitution than boys; so it is not remarkable that they should be born in greater numbers by well-nourished mothers. Kowalewsky conducted his experiments on guinea-pigs and rabbits, and his researches were extraordinarily thorough. He placed under the microscope the tissues of some of the animals on which he had experimented, he traced the effect of nutrition upon their supply of blood, and he showed clearly in what way this supply of blood acted in producing male offspring when it was poor and female offspring when it was rich. He then went on to examine the actual effects that the conditions of life have on the blood of women, and he showed that these effects would make the Tartars just what they are — a race remarkable for the preponderance of men and boys over women and girls.

It thus seems that we are at last in a way to obtain some knowledge of that mystery of life which from the social point of view is of enormous importance. We are now beginning to be able to see by what means the balance of the sexes has been maintained. We have numerous examples in history of wars and other social upheavals, where males have largely suffered, and yet where, within an apparently short period of time, the proportion of the sexes has been reëstablished. This goes to show that some mechanism must exist by means of which the number of males and females born is regulated.

The sex-equilibrium is like that of a gyroscope, where the greater the disturbance of position, the greater is the force tending to reëstablish its natural stand while in motion. The facts regulating the proportion of the sexes must be something of the same type; they are such that, the greater the oscillation in any one direction, the greater must be the restraining force that curbs and neutralizes the movement.

The wild, destructive energy of men who cannot find wives

Nature, however, uses rough methods. When a race is troubled by a superfluity of young men unable to obtain wives, and hard put to it to get a living, a fierce, angry, warlike spirit is born from the general discontent. As a rule, such a race at last explodes in wild, destructive energy; there are often intertribal wars, from which there emerges some great captain, like Tamerlane, who directs the young men from victory to victory over richer nations. Famine and poverty, on the other hand, are the medicines given to nations whose luxurious ways of life are leading to a superfluity of women and to the polygamous marriages which end in making a superfluity of women almost a social necessity. Pestilence has also been one of the terrible scourges whereby nature has driven man back into a naturally monogamous state of society.

It may be thought that at present there might seem to be no balancing force in the civilization we are now spreading over the world. We are conquering the agents of disease and discovering new sources of food supply, and thus increasing the influences which disturb the equilibrium of the sexes. Instead of going back to a simpler and a harder life, we are becoming luxurious. An ordinary artisan now has set daily on his table at meals articles of food which kings could not have commanded a few hundred years ago. The standard of living is continually rising, and wages are being forced up to meet the increased cost. Pestilence and famine are practically subdued. So there remains only war, and this, too, should be a diminishing menace.

The natural restoration of the balance between the sexes

Yet, in spite of all this, there is some reason for thinking that the balance of the sexes in western Europe will be restored within a few generations. Nature seems as subtle as she is strong: finding that she cannot maintain the equilibrium by means of the old forces of war and famine, she is employing more unusual means. Among the new economic conditions of our industrial civilization, none has been more generally deplored than the growth of luxury which leads to late marriages.

The far-reaching effect of giving woman an alternative to marriage

Young people will not begin married life on the small means on which their grandparents began. Perhaps our millions of business girls, factory girls, and servant girls have acquired a stronger spirit of independence Earning a considerable sum of money themselves, and being thus able to indulge their tastes for some of the showier pleasures of life, they want their lovers to be comparatively well off before they fix the wedding-day. In short, they have *an alternative to marriage*, so they lengthen the pleasantly irresponsible period of courtship.

The young men, too, are also moved by a zest for the amusements of the city. Until they are getting a wage which will keep two in comfort, they do not seriously think of marriage. The best of them struggle and save in early manhood with a view to giving their future wives as good a home as the fathers of the girls were able to establish late in life. No doubt many young couples among the working classes still face life together at an early age; as the young artisan oftens earns as high a wage as the older men, he is enabled to marry earlier than the men of the middle classes. But the same influences are at work throughout the nation, and the working class, too, generally is becoming more pleasure-loving, and putting off to a later period of life the frugalities that necessarily must follow on the double burden of marriage.

Now, the older a woman is, the smaller is the store of energy she possesses. It seems as though at about the age of thirty she begins to live on her capital-fund of nutrition, as men do. The fine physique of the modern athletic girl appears to be produced to some extent by the fact that she remains single for a much longer time than her grandmother did. Such a woman often appears as a splendid embodiment of womanly beauty, but she is, in fact, living on her energy, instead of storing it up.

So, by a different and more pleasant road, the modern woman arrives at a position similar to that occupied by the hard-worked and under-fed Tartar girl. In other words, she becomes the mother of boys. This is probably the true explanation of Professor R. C. Punnett's surprising figures of the excess of male birth in well-to-do districts of London as compared with the excess of female births in poorer districts.

The age of the mother which seems to affect the sex of the child

The effect of the modern late marriage in restoring the balance of the sexes has been tabulated by Dr. R. J. Ewart. Here are his tables giving the relation of the age of the mother to the sex of the child

All Births up to	Males	Females	Males per 1000 Females
19th year	29	44	659
24th year	226	264	856
29th year	437	455	960
34th year	716	617	1000
39th year	720	715	1007

If taken between the stated ages, the figures are as given in the following table.

	Males	Females	Males per 1000 Females
All births up to 19th year	29	44	659
From 20th to 24th year inclusive	197	220	895
From 30th to 34th year inclusive	180	162	1111
From 34th year and after	155	133	1165

It thus appears that young mothers have a tendency to produce more daughters than sons, while at more mature ages there is an excess of male children. There is the same difference in the offspring of young fathers and mature fathers; so that we can easily see how a self-regulated balance of the sexes is established. In a state of society in which women are scarce, there is a great demand for them in marriage. Therefore they naturally wed early in life, and thereby tend to produce an excess of female children, thus neutralizing the condition of things which recently existed. Should the men be in the minority, on the other hand — as is at present the case abroad — the women will marry later in life, and an excess of male children will result from these marriages.

A natural tendency which seems to counteract the effects of better food

Thus at the present time there seem to be two tendencies at work which are of a nature to offset each other, so that the net result should be to preserve the balance between the sexes. Such is Dr. Ewart's theory. He has not yet proved one part of it, perhaps — that which makes an excess of women result in raising the mean age of maternity. Happily, another factor, as we have shown, is concurring to this end.

When women are in excess, as they are now in the leading emigrant nations, the growing independence of a large number of girls, who by reason of their work in factories, households, and offices have an alternative to married life, should bring about a general decrease in early marriages. We may regard the British nation as now being at an extravagant height of female preponderance, but in the natural course of things a more numerical equality of the sexes will be established.

It would be very interesting to know whether an analogous tendency holds in the converse case, whether an excess of males similarly tends to correct itself through raising the average ages of husbands relatively to those of wives. But this subject has not been sufficiently investigated to lead to definite results.

PIONEERS

ALCUIN

Founder of University Education in Europe

ALCUIN, or, as he liked to be called, Flaccus Albinus, was a celebrated ecclesiastic and the most distinguished scholar of the eighth century, the friend and adviser of Charlemagne. From Charlemagne sprang the university movement on the continent of Europe, and Alcuin was the educational inspirer of Charlemagne. When learning had almost perished in Europe, under the wave of barbarism that swept away the Roman Empire, it found a sanctuary in the north of England, through scholarly monks who arrived by way of Ireland and the west of Scotland, and in the middle of the eighth century York was the greatest educational center in Christendom, and had the most valuable library. Here, in 735, Alcuin was born. Educated in the cloister school, he became first one of its teachers, and, at the age of forty-three, its master, with a reputation that reached far beyond his native land. Indeed, he was known personally abroad, for we have evidence that he had visited Paris and met Charlemagne before, in 781, he journeyed on a mission to Rome. Returning, at Parma he again met Charlemagne, who was so delighted with his personality and aims that he invited him to come to his court at Aix-la-Chapelle, and there establish a palace school. Alcuin complied, and from that nucleus of patronized learning medieval education grew, with its great universities of Paris, Tours, etc.

Alcuin's motive was religious. In his own words, he wished "so to teach children grammar and the doctrines of philosophy that, ascending the steps of wisdom, they may reach the summit, which is evangelical perfection." His ambition was to reestablish education as it existed in the days of St. Augustine; and to this end, though his instincts were conservative, and he had a distrust of the old-world poetry, he promoted learning on classical lines, taking the "seven liberal arts" of grammar, rhetoric, logic, arithmetic, geometry, music and astronomy as his curriculum, thus following the example of the school he had left at York.

Charlemagne himself, his four sons, and two daughters became his pupils, and the king helped Alcuin to spread the movement for education in and through the monasteries. Alcuin wished "to make the library the armory of the monk." But presently he tired of the roughness of the Frankish court, whereupon Charlemagne, who continued to be his admiring friend, made him, in 796, abbot of the great monastery at Tours — a princely domain. Here Alcuin continued his educational work until Tours became the center of French culture and of influence in the Church, and had gathered a library that rivaled that at York. At Tours, in 804, this energetic and captivating pioneer of education died.

The special feature of the work of Alcuin was that he not only stimulated education in the religious houses, but extended it to the laity.

The parish priests were strongly encouraged to teach; the cathedral schools grew into a position that would now be described as secondary; and the palace school was the forerunner of the university foundations. Though we look back now with wonder at the narrowness of the scholasticism of the medieval age, its establishment was a great advance on the rough and iconoclastic ignorance of the ruling class that preceded the liberal movement of Charlemagne; and the change was largely due to Alcuin.

A considerable amount of writing by Alcuin has been preserved, though some is of doubtful authenticity, and none of it is of a character to sustain a literary reputation. It is the intellectual stimulus which he imparted and the long line of scholars which owed to him its existence that form his true monument. He was the one great Englishman who lived between Bede and Alfred, and may fairly be said to have founded the Continental education which survived when Danish barbarism had swept away the venerable culture of Yorkshire and Durham.

HENRY BARNARD

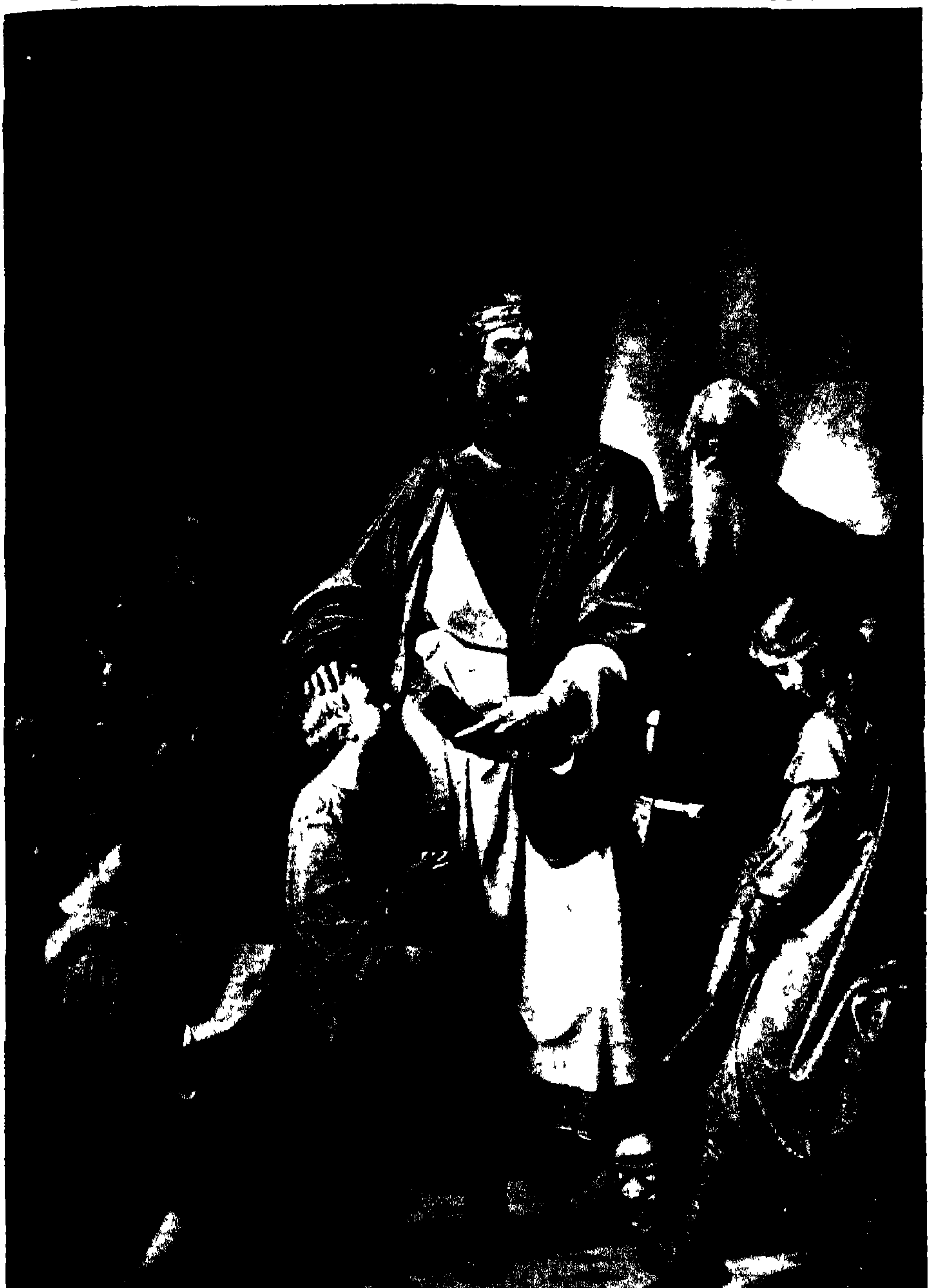
The Nestor of American Education

HENRY BARNARD was born in Hartford, Connecticut, January 24, 1811. He belonged to a very old family and the house in which his father was born is one of the few remaining types of the New England homesteads of two hundred years ago left standing in the neighborhood. He was sent to the district school till he was twelve years old, and did not find its attractions as strong as those revealed by the stories he heard from sailors, and the boy decided to run away to sea. His father, seated near an open window, overheard the young plotter agreeing with a comrade to start on the following night. He wisely made no reference to the matter but sent him the next day to the Academy of Monson, where his surroundings roused in him both a liking for study and an interest in the industrial problems of the numerous factories in the neighborhood. After leaving Monson, he studied with a private tutor, and completed his preparatory training at the Hopkins grammar school in Hartford. He entered Yale when he was some months under sixteen and graduated in 1830, with honors. Many young men have "dreams of great things to do" but young Barnard did more than dream. He marked out a course of training for himself, as he was convinced that the regular curriculum provided by Yale was not wide enough for the lifework he had chosen. He studied to acquaint himself thoroughly with the development of Greek and Latin civilization, familiarized himself with English literature, and was recognized as the "best read man of his class." But the thing in which he was most interested was the development of his oratorical powers. He was from the time he entered college an enthusiastic member of the Linonian Society and became its president. He had a wonderful knack at impromptu speaking, which developed rapidly with experience and ripened scholarship, until he became one of the most agreeable and convincing orators of America.

Barnard had no intention to devote his life to educational work when he left college. His purpose was to make law his profession; but his great aim was to become a public man. He was admitted to the bar in 1835, and decided to visit Europe before beginning to practice. He traveled extensively on foot in England, Scotland and Switzerland, made a careful study of educational laws and visited Pestalozzi's school in Yverdon. When he returned to Hartford in 1836 he was nominated for the representation of his city in the state legislature without even being consulted by his friends, and his career in the House was marked by energy in behalf of prison and school reform.

In 1838 Barnard was asked to bring a bill for better local supervision of schools before the legislature, and his speech in introducing the measure was a brilliant effort which gave to educational questions a dignity never before accorded them. The bill passed both houses unanimously, and Barnard was appointed one of the eight commissioners of the Connecticut Board of Education, and its secretary.

CHARLEMAGNE THE PATRON OF ALCUIN



CHARLEMAGNE, THE PATRON OF ALCUIN'S EDUCATIONAL MOVEMENT, VISITING A SCHOOL

In 1842, owing to political changes, the board was abolished and for some time Barnard traveled throughout the United States, lecturing in every state but Texas, and conducting conferences in societies to elevate public sentiment in regard to education.

After the passage of the Rhode Island School Act in 1843, Governor Tennor sent for him to become state superintendent of schools, and in this office he manifested the same zeal, virtually revolutionizing the educational system of the state. During the five years he was in Rhode Island he held more than thirteen hundred educational meetings, distributed more than sixteen thousand educational pamphlets among teachers and parents, established twenty-nine libraries of not less than five hundred volumes, and made the Rhode Islanders lovers of free public schools. In 1849 he resigned his position owing to nervous strain, but after a well-earned period of rest was again recalled to the educational field, and became principal of the Connecticut State Normal School and state superintendent of schools for four years, until again forced to resign by ill-health. Every reform measure which political intrigue had repealed in 1842 was reëstablished, not only in the statute book, but in the spirit of the people.

In 1858 Barnard became chancellor of the University of Wisconsin. His chief purpose in accepting the position was to bring about a unity of all state educational forces from the kindergarten to the university, and to make the complete system free. In the spring of 1860 he had nervous prostration, and was unable to carry on his work for nearly two years. After waiting for eight months the state reluctantly accepted his resignation. His efforts in Wisconsin were chiefly directed to the improvement of the system by the establishment of graded schools, with a public high school where young men and women could be prepared for the university or for business, and upon the elevation of the teaching profession. He began at the foundation in order to provide better qualified men and women for admission to the university.

In 1866 Dr. Barnard was elected president of St. John's College, Annapolis, but he resigned the following year to become the first commissioner of education for the United States. He remained four years in Washington, and organized the Bureau of Education, issuing four very valuable reports. His literary work is important in subject and extent and admirable in treatment. The thirty-one volumes of his *American Journal of Education* and the fifty-two volumes of the "Library of Education" form the most complete encyclopedia of education ever issued. In addition he edited the *Connecticut Common School Journal*, for eight years, three volumes of the *Journal of Rhode Island Institute of Instruction*, seven volumes of "Papers for Teachers" in Wisconsin, and over eight hundred tracts on educational topics. In doing so, he spent out of his private fortune more than $40,000. Horace Mann, his greatest co-worker, said of Dr. Barnard, "His Rhode Island work is the greatest legacy yet left to American educators." Dr. Barnard died in 1900.

EDWARD BELLAMY

A Dreamer of Social Reconstruction

EDWARD BELLAMY, the last writer who popularized an ideal State — a communistic Utopia — was born on March 25, 1850, at Chicopee Falls, Massachusetts. He studied as a young man both at Union College and in Germany, and, returning home, was admitted to the bar in 1871, but almost at once was drawn aside into journalism, and became, first, assistant editor of the *Springfield Union*, and then of the *New York Evening Post*. His early incidental writing took the form of novelettes, of which he published three with fair success: "Six to One," "Dr. Heidenhoff's Process" (1879) and "Miss Ludington's Sister" (1884).

These were fairly successful, but it was not until the appearance of his "Looking Backward, 2000–1887," in 1888, that he became widely known. The book gained immediate and enormous popularity, passing through many editions in all English-speaking lands, and securing translation into the principal foreign languages.

At first it was accepted as a romance pure and simple by people who read only for passing interest; but Bellamy had put into it his deeply felt convictions, and was in dead earnest in believing that his suggested reorganization of society was a possibility, so he devoted himself to the propagation of his ideas in the press and on the platform. But his book lost as politics the hold it had gained as fiction. A sequel, entitled "Equality," proved unsuccessful, and a society formed to give the impetus of party to the author's ideas has not lived. Bellamy died at his birthplace on May 22, 1898.

He was a brilliant, optimistic man, who thought social changes might be made by a *coup de main* which can only be brought about in the most gradual way. Whatever may be thought of Bellamy's ideal State, the attempt to realize it was clearly ill-timed. Much of the organization of society described in "Looking Backward" was adapted from Sir Thomas More's "Utopia" to fit modern conditions.

The introduction was ingeniously arranged — a great improvement on the customary traveler from unknown shores who describes his experiences. Bellamy imagined a rich Bostonian of the year 1887, who to overcome insomnia built himself an underground retreat in which, when his ailment becomes specially troublesome, he is soothed to sleep by a mesmeric practitioner. While lying thus in a state of trance the house was burned down, the secret chamber remaining undiscovered. The owner was supposed to have perished in the flames with his confidential servant, and the mesmerist had left the country. In the year 2000 the vault is accidentally disclosed, and the sleeper recovering from his trance, finds himself in a new world, but as youthful as ever. He thinks it is next morning, but really it is 123 years later.

The substantial part of the book — lightened by old and new love experiences — consists of the discovery by the awakened man of how the social problems of the end of the nineteenth century have been solved before the coming of the twenty-first century.

In the interval the combinations of capital and the combinations of labor have become so complete on each side that a coalescence of all industry into a single State has been imperative, and the working of this ideal commune is described, so as to meet the various objections which defenders of individualism and the unlimited accumulation of private property would advance today. Poverty is abolished. Each member of the community is trained to do, with honor, the work for which he is suited — the doing of other work being less agreeable to him — and the rewards of industry and endeavor are such as each can most freely enjoy. Science has made enormous advances, and most of the evils of nineteenth century civilization have disappeared, and, indeed, are already regarded as almost incredible records of a barbarism become well-nigh unthinkable.

The interest of Bellamy's imaginative social construction is that it uses the materials which the optimistic philosophers of the past have accumulated, and cleverly adapts them to the requirements of today, and the problems that have arisen most recently from the onward passage of social evolution. It therefore has a much greater sense of reality than such ideal forecasts as More's "Utopia."

WILLIAM BOOTH

The Founder of the Salvation Army

WILLIAM BOOTH, founder and "General" of the Salvation Army, was born at Nottingham, England, on April 10, 1829, and was educated at a private school. The son of Church of England parents, at thirteen years of age he revealed a precocious independence of thought by renouncing the church of his family, and allying himself with the Wesleyan Methodist connection, whose services, he said, were more interesting and appealing. His religious convictions did not become quickened, however, until two years later, when he was "converted" by the preachings of an American revivalist. Fifty years later General Booth wrote of that event: "The hour, the place, and many other particulars of this glorious transaction are indelibly recorded on my memory."

Booth and a few young friends, fired with a zeal matching his own, began to hold services on their own account, services which were in almost every particular the prototype of those which have since become an established feature of Salvation Army procedure. The little band acted nominally as a sort of guerrilla ally of the forces of the chapel with which it was associated, but when at seventeen Booth was asked by his pastor to become a local preacher, and enter his name upon the connection "plan," he refused, pleading his youth, but really recognizing that greater opportunities lay in the path that he had chosen. Later he did yield to pressure, to find himself, as he said, "hooked into the ordinary rut, and put on to sermon-making and preaching." But he was not born permanently to serve under the orders of others and, relinquishing his mission, he went to London, and for three years was in business there.

At the end of that time he renewed in the metropolis the open-air services which he had begun at Nottingham. But he now combined mission work with study, and, surprising though it seems today, he became a Wesleyan minister and preached with such effect that his church appointed him evangelist to the whole connection, in which capacity he conducted services in the chief cities of the country. He seems to have been rather a thorn in the side of his church, however, for he was eventually bidden to return to regular duties, and, with unusual compliance, settled down to a pastorate at Gateshead. He had married a gifted, helpful woman, and for a brief period was at peace. At the end of four years he was ordered to move on. His congregation wanted him to remain, and he desired the same thing. As his chiefs were inexorable, he resigned his position in the Wesleyan Church, and became an independent itinerant preacher, backed by the efforts of his wife, who was as forceful and a more cultured speaker than himself.

At first they preached in chapels which remained open to them, holding open-air services beforehand, and then leading their congregation into the building afterwards, from the highways and byways.

But this plan was shortly given up, and the open-air service became the established feature. After campaigns in many directions, Booth established himself in London, opening, in premises which had been a disreputable Whitechapel bar and tavern, the East London Christian Revival Society. That was in 1865, and from that mission grew the Salvation Army. The organization had always a semi-military character, and this was enhanced, on the suggestion of Mrs. Booth, by putting their adherents into uniform. The final name was the result of what Booth afterwards considered an inspiration. He was drafting the annual report of his mission, and was writing "The Christian Mission is a Volunteer Army." Then, he afterwards used to say, "Something flashed across me. I scratched out the word 'Volunteer' and substituted 'Salvation.' It was a memorable inspiration." The movement spread like a fire through the land, and beyond it to other lands. The army sought primarily the souls of men, but incidentally they saved bodies, too.

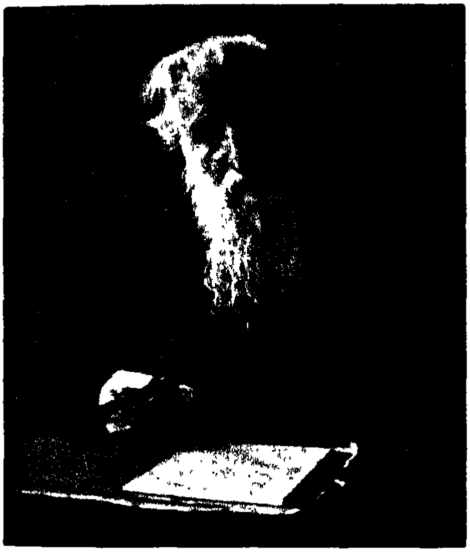
In 1890 the famous "Darkest England" scheme was launched. The idea was the General's, but the language was W. T. Stead's.

The scheme was one of the greatest projects for social reform ever presented by an unofficial organization. It was a comprehensive plan to carry material welfare as well as spiritual salvation to "the submerged tenth." It embraced labor colonies at home, emigration to Britain's overseas-possessions, rescue homes for the fallen of both sexes, adults and children; food for the hungry, clothes and shelter for the homeless. Booth raised half a million, and was able to carry out a scheme which, although short of his ambitions, was by far the most effective attempt at a great social regeneration which was ever witnessed in Great Britain.

General Booth worked unweariedly to the end of his life. Always a great traveler, he hastened his steps as the end approached, and by the fastest trains, fastest steamers and the fastest automobiles sped from town to town, from country to country, from continent to continent.

persecution and obloquy, which had so long followed the army in England, all died away during the reign of King Edward VII, who, with Queen Alexandra, took a deep interest in the work of the unwearying evangelist, and caused the Salvation Army to be officially represented at his coronation. University and other honors were showered upon him, his journeys were triumphal progresses, through cities where once the mob used to stone him.

Towards the close of his days his eyesight was severely affected, and finally he became totally blind. He died on August 20, 1912, without exaggeration mourned by the whole civilized world.



WILLIAM BOOTH

He left behind a remarkable organization. The Salvation Army at his death comprised nearly 21,000 officers, cadets and employees, and 9130 corps and outposts distributed over fifty-nine countries. His eldest son, Bramwell (born 1856), who had been his chief of staff, succeeded him.

In the United States the work was at first in charge of the founder's second son, Ballington, and his wife, who, not wholly in accord with the plans for their campaign made in London, withdrew from the Salvation Army in 1896 and started a similar organization known as the Volunteers of America.

Some idea of the magnitude of the Salvation Army work in this country may be gained from the following figures. In the fall of 1920 the Salvation Army had in the United States 1030 corps and outposts; 3649 officers and cadets, 52 hotels for men and 7 for women with a total accommodation for 5646 (beds supplied for the year 1,555,546, meals 494,513); 82 industrial homes with accommodations for 2118 (420,743 beds and 1,260,032 meals supplied); 3 children's homes, 19 slum-posts and nurseries; and outside employment was found for 52,219 men and 13,034 women. There are separate editions of their daily paper, the *War Cry*, published for each of the three territories into which the country is administratively divided.

ZEBULON REED BROCKWAY
An American Reformer of Criminals

ZEBULON REED BROCKWAY was the man of widest experience of all time in the reformation of men after they had started on a criminal career. He was born at Lyme, Connecticut, on April 28, 1827. At the age of twenty-one he was a clerk in the Connecticut State Prison, and passed from there through a number of official positions in connection with prison and reformatory work that enabled him to gather unique experience.

In 1857 he became deputy superintendent of the Albany penitentiary. Three years later he was appointed superintendent of the Munroe County (N. Y.) penitentiary, and in 1861 he became the head of the Detroit (Mich.) house of correction. This experience enabled him to formulate schemes for remedial treatment of men who were beginning a life of crime, so as to bring them back into the body of reputable citizens. In 1876 the state of New York, which had determined to deal in a remedial way with first offenders on the lines recommended by Brockway, appointed him superintendent of its new reformatory at Elmira, and gave him a free hand in the most remarkable manner. For twenty-four years he held that position, and made the reformatory a model that was copied, more or less, by almost every country.

In 1900 he retired from Elmira, but in the remaining years of his life he continued his interest in remedial prison work as a lecturer on penalogy at Cornell University He died on October 21, 1920

The Elmira reformatory is a material embodiment of the man and his life's work It brought Brockway's ideas into operation in the very year when Lombroso published his much discussed book "L'Uomo Delinquente," and the criminal became a serious subject of scientific study Up to that time prison had been a punitive institution, which, incidentally, did harm to every one who came within its influence The question Brockway asked himself was whether the prison could not be made to do a man good, and return him to society able to take his place in the ranks of honest industry and keep it with credit Through a long series of years he proved conclusively that this remedial result can be attained in 80 per cent of cases if the criminal is taken in hand after his first known serious offense is committed, and is trained carefully for the life after he leaves prison

The Elmira reformatory stands in 280 acres of ground, the walled part covering 16 acres It can accommodate 1400 male inmates between the ages of sixteen and thirty, and it cost nearly two millions The planning of the prison, the system of treatment and all the details of management were left wholly in Brockway's hands, and the only criticism of the institution that ever appealed to outside observers was that the liberty of so many men was left under autocratic control That was a theoretical objection, actually, the facts were wholly favorable

At the basis of the treatment was the indeterminate sentence No prisoner could tell when he would be discharged, except, of course, that he could not be kept beyond the expiry of his sentence He might be released, however, quite irrespective of the length of time named in the sentence, if he showed rehabilitation of character and a power of earning his living Life inside the reformatory was regarded not as punitive, but as preparatory to a better life outside.

The usual term was then about two years, and in that time it was found possible to train a man for citizenship Conditional release was granted for six months and after that period supervision ceased and the release became absolute, even though the original sentence might be for twenty years

Reformation by industry was the keynote of the Brockway gospel That punishment never reformed anybody, but that skilled industry may reform almost anybody, was Brockway's firm belief The success of the indeterminate sentence caused its adoption in many other prisons

LUTHER BURBANK

The Gardener whose Ways are Nature's Ways

LUTHER BURBANK whose whole life has been given to the study of how nature does things was born at Lancaster, Massachusetts on March 7 1849 The son of an English father and Scotch mother both of them studious people Burbank though in poor worldly circumstances was happily placed in regard to educative opportunities As he grew up he read everything that came his way bearing upon his hobby — botany He had no pets or toys only plants with which to beguile his leisure School-days ended, he was placed at work in the factory in which his father was already employed, but preserved his love for gardening Noticing one day that a certain potato-plant bore a seed-pod, he preserved the seed, and from it raised a potato which proved far superior to others in disease-resisting qualities as well as in fertility As there was a threat of a potato famine at the time he was able, without difficulty, to sell his new growth for $150, and it is stated today that the Burbank potato cultivated far and near, has added nearly twenty-five million dollars to the wealth of the agricultural community of America

Ill-health drove Burbank out of factory life and with ten of his potatoes and a very small sum of money he set out for California, the botanist's land of promise He experienced great privations, was frequently without money or food, but obtained work at last, and managed to save

THE BURBANK ORIGINAL "ROYAL" WALNUT TREE

This tree at twenty-two years of age was ninety-six feet in height, with a spread of sixty-four feet of branches, and a girth of nine feet three inches six feet above the ground and the same at twelve feet.

sufficient to enable him to rent a small nursery. The clouds of misfortune began to roll away with his first audacious attempt to mold nature to his will.

He received an order to supply 20,000 prune-seedlings within nine months. As eighteen months are required to raise a prune-seedling the task seemed impossible. But Burbank had his own ideas upon the subject. He planted 20,000 almond-seeds, which germinated, and at the end of six months had grown so rapidly that he was able to graft prune-buds upon them. He delivered the prune-seedlings within the specified time, and the orchard in which they were planted is now one of the finest in California

LUTHER BURBANK

This shaped his future career. Little by little he withdrew from the ordinary routine of the nursery-garden to develop new varieties of fruits and flowers, by cross-fertilization, by budding, and by the raising and multiplication of self-fertilized freaks.

In 1893 Burbank retired from the nursery business and devoted himself entirely to the task of propagating new growths of flowers, fruits, vegetables, and cereals. He had a long, hard struggle, for fame and capital do not invariably bear one another company. But in 1905 a notable thing happened.

The Carnegie Institution of Washington decided to grant Luther Burbank an annual $10,000 for ten years, to free him from financial care and to enable him peacefully to pursue his investigations for the benefit of the community.

The results attained are among the most surprising in the whole annals of botany He has produced new and vastly more fertile wheats; he has robbed the edible cactus of its thorns, and made it fit for the food of man and animals, so that in the near future he hopes to see the old and formidable foe of animal life in the desert supplanted by the progeny of the edible cacti of his own nursery. The deserts, he says, will provide in this way a food supply of more than twice the amount required for the whole population of the world. Noting the havoc wrought in California by late frosts, he has evolved trees whose foliage and buds are undamaged by frost, trees which will bloom earlier and fruit later than any others He has blended the plum and the apricot into a plumcot, a delicious stoneless fruit, has given the world a thornless white blackberry; has multiplied the varieties of apples and pears, so that he has one apple-tree bearing upwards of seventy distinct species, large, small, sweet, tart, red, green, golden. He is constantly making new fruits; new vegetables, new grasses, new nuts, new flowers.

All this is the outcome of his own patient investigation, selection and pollination. His varieties of plums are said to number 300,000; his peaches and nectarines, 60,000; almonds, 5000, and so on. But these are only steps in his ladder of creation. All the 300,000 plums may some day be reduced to half a dozen varieties. His white thornless blackberry was the product of 65,000 separate growths. Without university training, or any special advantage not open to all, Burbank has revealed more secrets of nature in regard to the potentialities of her vegetal growths than any complete generation of botanists combined. He obtained his knowledge of general principles from books, but his talent for applying those principles was his own priceless inherent gift.

THE ULTIMATE UNIVERSE

The Mystery of the Two Worlds. What is Mind? No Matter. What is Matter? Never Mind

THE MATERIALIST IMAGE WITH FEET OF CLAY

THE mind of the student, surveying the vast multiplicity of things, naturally seeks to reduce them to a list or category, so that it may be possible to form "clear and distinct ideas," and to formulate laws of nature's working.

The tendency to classify lies deep in the mind; we all necessarily adopt this process in all our affairs. There is no other manner in which to get a grip of things, for otherwise their number and variety are too great for our minds to grasp. On the other hand, much of the business of science consists of breaking up and analyzing, distinguishing between this and that, because they differ in some points, though perhaps are alike in many more. These two contrary processes go on all the time; and the triumph of science is when they are found not to contradict but to help each other, so that, the more we distinguish and separate, the more we are able to simplify and unify, until the great scientific ideal of "unity in multiplicity" is realized.

Plainly the next task before us, in these chapters which are introductory to the study of the universe, and therefore to the study of all the sciences, is to endeavor to reduce things to their ultimate categories, so that we may know all the kinds of beings of which the universe is made, and may be able to refer every new object to a place on our list. If we can do this we can do much more, for it means giving us definite ideas of the elements of our problem; and thereafter we should be able to discover the great modes of interaction between one kind of being and another — those modes of interaction which we call "the laws of nature."

We may, for instance, have often noticed that the same thing happens over and over again in the same circumstances, and call that a law of nature, but that is not enough for our purpose. If our science is to be really worthy of the name, it must include not only particular laws of nature but also those that are general and universal; and if there are to be general and universal laws, they must deal with the ultimate categories of things That is why a list of things is a necessity at this stage.

If we consider and survey all the different kinds of beings of which we have any experience, one obvious and transcendent division of things first meets us, compared with which all other distinctions are simply trivial. On the one hand, there are things more or less visible and ponderable, which for many ages have been called "matter"; and on the other hand, there is a something, neither to be seen nor weighed, which knows and reasons, and this we call "mind." As the witty proverb has it: "What is Mind? No matter. What is Matter? Never mind."

True, there is a final and peerless imbecility which denies the reality of mind, though that denial obviously invalidates itself, since it is mind that makes it. Here we shall not be so foolish. Our study in this section is wholly concerned with that which is not mind, but it is mind that writes and mind that reads; and we shall not so utterly stultify ourselves as to deny the primary condition of all our study, even though it is not to be called upon here to study itself. Our first division of the sum of all finite being is therefore into the ultimate categories of mind and matter.

The everyday use of "matter" inadequate to cover the physical universe

From this point we must confine ourselves to the second of these until we have much improved upon the idea as the mere word "matter" states it. Rather than speak of mind and matter, we should do better to speak of the psychical universe and the physical universe, where under psychical we include all those realities and operations which formally involve life, the highest form of which is intellectual life; and under physical we include all else. These are not properly two utterly different and separated worlds, for they have their intimate connection and necessary dependence one upon the other and together form the complete universe.

We must use some such term as "physical," because the word "matter" as used in its ordinary, everyday meaning is entirely inadequate, and only refers to a mere fraction of the physical universe. Indeed, such is the present poverty of language that it would be more consistent to speak of mind and not-mind. Our business now is to reduce not-mind to its ultimate categories.

The air we breathe is as much matter as are the hardest rocks

First on the list, as we may begin by supposing, is matter — that is, ordinary ponderable matter. Its claims are obvious, but we shall see that they may not be substantiated as fully as at first supposed. Meanwhile, we grant them. Matter includes all material substance, irrespective of size or distance. Sirius and the sun are examples of aggregations of matter, and so is any of the punctuation marks on this page. Questions of near and far, large and small, celestial or terrestrial, are irrelevant — matter is matter everywhere. Questions also of solid, liquid, gas, are irrelevant. Such matter as makes up water is equally and simply matter, whether it exists as ice, snow, hail, liquid water or water-vapor. The air we breathe is as much matter as the hardest and heaviest rock; it may be liquefied or solidified, but is no more matter in these states than in its usual gaseous state.

The materialist whose doctrine has received most remarkable condemnation

There is about matter, at least in the solid or liquid state, a satisfactory impression of reality. We are not so sure about the gaseous form of matter, but the casual mind tends to regard matter in general as the most real of realities; in fact some have gone so far as to hold that matter is the only reality and to deny the existence of anything else. Hence there is derived a definite theory of the universe, appropriately called "materialism."

This hopeless and uninspiring notion of things had its heyday in the second half of the last century, at the dawn of the modern scientific era. It has received in recent years the most remarkable condemnation. It is a doctrine that is due in great part to overinsistence on the value of the observational sciences and to an extreme reaction against the "metaphysical" sciences, or rather against the methods of those who exaggerated aprioristic reasoning even in the domain of physical facts and sought to explain things and happenings without regard to physical observations at all. But true science, as well as true philosophy, must avoid both extremes. And even the methods of observation on which materialism based its findings, when urged to their limit, show us that there are some things which cannot be weighed and measured by the balance and the yardstick. The materialist image of the world had feet of clay and they have crumbled into dust. Ponderable matter itself has been found to be less ultimate than it was thought to be; and the theory which built mind and all other existence thereon is left "to point a moral and adorn a tale."

As we have already seen, the modern analysis of matter resolves it into electrons, and electrons themselves involve electric energy in their make-up. Moreover these electrons are found to be alike in different kinds of matter, that is in different chemical elements, while electric energy is but one of the many forms of physical energy all of which are, as we know, mutually convertible one into another.

"Ether is the mother of matter" and energy is its father

Our list of things thus becomes smaller and more profound. All forms of matter, "from stars to street-sweepings," all compounds and all elements, now seem to have a fundamental likeness which formerly was not even suspected; and even inert matter itself we now know involves vast stores of internal energy which but wait the proper conditions, such as are found, for example, in radioactive substances, to be liberated from the atom and to become externally manifest and operative. So universal, so persistent is energy, so capable is it of manifesting itself as light, heat, motion, electric, magnetic, chemical energy, atomic and molecular energy, that we may be inclined to think that everything physical is after all simply energy in some form or other and to ask whether anything else remains.

The answer is that we have not yet reckoned with a mysterious something, invisible, yet the vehicle of all light, which is not matter in the ordinary sense, and is not energy: and this something is called "the ether." It comes to this: that for the older pairs of terms, "matter and energy" or "matter and motion," we must substitute "ether and energy." Our list of things, so far as the entire physical universe is concerned, may be reduced to these two, and to them alone. We make this statement, however, with some reserve; for we must confess that we have not as yet arrived at a sufficiently clear knowledge of the internal constitution of matter to enable us to state categorically and without hesitation that matter is intrinsically and entirely a combination of ether and energy; but towards that goal science is tending.

As Gustave Le Bon has put it, "Ether is the mother of matter," and perhaps we may now say that energy is its father. Le Bon has given us a most suggestive analogy when he compares the genesis and dissolution of what we call "matter" to the formation and melting of icebergs in the ocean. That ocean, universal and continuous, is the ether.

Here is an idea which has grown from small beginnings, and has survived much ridicule, until it has attained preëminence in modern thought. Just as electricity was at first no more than a singular property of amber — of which the Greek name is "electron" — and has now become recognized as a form of energy which is involved in the constitution of all matter, so the ether, originally "invented" as a necessity of rational speculation for particular purposes, has become recognized as the universal medium, the womb and tomb of all material things.

The mysterious something that was supposed to carry light

We first hear of what used to be called the "luminiferous" — that is, the light-bearing — ether. Sound travels through ponderable matter — air, water or rock. Where there is no such matter, there is no sound; no earthly sound can reach the heavens. But light travels from star to star, or sun to planet, where there is apparently no matter at all. Men have believed, as Newton did, that light consists of a multitude of minute bodies, called by him "corpuscles," which are shot through space from the luminous object. But when this "corpuscular theory" of Newton's was found to be unsatisfactory, there followed the "undulatory theory," which declared that light consists of undulations, or waves. Plainly we must inquire — waves in what? For these waves are evidently conveyed where there is nothing that we can perceive by our senses. We are bound to assume the existence of a medium, and that, from its function, was called the "luminiferous ether." About it no more was asserted than that it was *not* sensible matter, but was certainly real, and that it was capable of conveying waves, so that it must have the property, familiar in many forms of matter, which is called "elasticity."

But Newton's name is associated with another theory which has stood the test of time much better than his corpuscular theory of light. He declared that the motions of the planets can only be explained by the existence of an attractive force exercised between them and the sun.

The unseen ether that is more real than are the things we see

Now, if a force or an action be exercised, we are bound to believe that there exists some medium through which it is exercised. The alternative is to believe in "action at a distance," the name for action exercised by one thing upon another without any sort of intervening medium.

Now, "action at a distance" between two material bodies simply cannot be imagined, and gravitation is a fact; therefore there must be a medium, filling space, which we may call "the ether." And we may not unreasonably suppose that the ether or medium which conveys light also conveys the force of gravitation; nor will this view be any the less satisfactory if the physicists discover, as they may, that the force of gravitation is electrical in nature, as we know light to be. At the present day we are acquainted with a large number of other forces and radiations, such as magnetism and radiant heat, which also demand the existence of a medium for their transmission, and that medium is likewise the ether. The positive, scientific, objective reality of this ether needs to be insisted upon, as many critics who are not acquainted with recent scientific developments still incline to the view that the ether is a kind of legend, not to be taken seriously. To modern students of these subjects, excepting perhaps a certain class of mathematicians, the ether is far more real than obvious matter, though the type of mind will perhaps always persist which denies the reality of whatever is impalpable.

The great chemist who thought ether to be one of the chemical elements

Certainty that the ether exists is not incompatible with the doubt regarding its properties. The doubt, and the differing opinions of students, evoke the jeers of critics who are themselves so far removed from giving any help that they are totally incapable of appreciating even the difficulties which are involved in the problem, and which, though not yet solved, are in process of solution.

The great Russian chemist Mendeléeff propounded in the last years of his life the view that the ether is really none other than a form of ordinary matter, that it is, indeed, one of the chemical elements; and he endeavored to find a place for it in the table of the elements which it is his lasting honor to have given to the world. The opinion of Mendeléeff is not accepted, but it is worth recording, not only for its historical interest, but particularly because it shows how a great student of the forms of matter was so convinced of the substantiality of the ether that he could place it on a par with ordinary matter, and include it among the chemical elements.

If we consider the motions of the heavenly bodies, we begin to realize the difficulty of the problem before us. We know for certain, since it cannot be otherwise, that space is filled with a something, which we have agreed to call "the ether," though the name matters nothing. As the earth travels through space many miles in every second of time, what does it do to the ether, and what does the ether do to it? Does the ether part in front of it, as the air and water part in front of a ship? If so, to what extent does the ether retard the earth by its having to be parted in front of it, and by its friction upon it as it passes? If such friction occurs, no matter how inconceivably minute its extent, then it is only a matter of time for the speed of such a body as the earth to be so much retarded that it can no longer maintain an orbit, and must sooner or later fall headlong into the sun.

Does the earth divide the ether as it passes through it?

Other astronomers prefer to consider the possibility that, as earth or sun or any star or comet moves through space, the ether of space travels through the material body, as water might move through a porous body such as a sponge.

If we endeavor to compare the ether with ordinary matter, we naturally incline to the view that it must be inconceivably light and rare and tenuous, compared even with the lightest form of matter that we know, which is hydrogen gas.

The idea that the earth is an "empty" part of the universal ether

Yet the mathematical astronomers are more and more inclining to accept a view entirely opposed to this, and are crediting the ether with a density and potency which transcend all ordinary matter, however concentrated; and we have indeed been latterly asked to conceive of material things, such as our earth, or any lesser or greater portion of matter, as places of comparative emptiness and vacuity in the universal ether — a notion which directly contradicts all that we naturally suppose, and which yet has much to be said for it.

If we are asked as to the structure of the ether, we can only reply that we suppose it must be structureless. It must be continuous and non-atomic, just as definitely as matter, or "ordinary matter," is discontinuous and atomic. Something happens in it wherever what we call matter is to be found; and it suffers stresses of some kind whenever it transmits any form of what we call ether-waves, though it must be questioned whether the term "waves" is much more than a figurative expression.

Having satisfied ourselves that the ether exists, and that it is one of the two ultimates of the physical universe, we must ask what is its relation to the other entity, which we call energy. Here we are in deep water, but certainly the more obvious view is the wrong one. We incline to think of the ether as something, itself passive, which is acted upon by matter, or acted through by matter, as when gravitation attracts, or when radiations of heat or light are poured forth from hot or glowing bodies.

This conception of the ether is at variance with the deductions of those who have studied it most. As Sir Oliver Lodge and many others have pointed out, the ether is crammed with energy, very nearly measureless in quantity. We cannot, as yet, tap that energy, any more than we can tap the energy inside the atom; perhaps the key to the one may be the key to the other. But there it is; and any mental picture of the ether which omits to include it is inadequate and useless.

The transformations and the interactions which constitute the world processes

Let it be fully granted that the problem of constructing a mental picture of the ether which will satisfy all the demands made upon it by science is at present insoluble. It will yet be solved, and meanwhile we have enough to justify us in the assertion that the most ultimate and simple category of the physical universe which we can frame according to our present knowledge reduces the list of things of which it consists to two — ether and energy.

What we have called "cosmic evolution," therefore, depends upon and consists of the transformations and the mutual interaction of ether and energy. This statement practically agrees with Herbert Spencer's conception of physical evolution, except that we substitute "ether and energy" for "matter and energy." These transformations and interactions proceed in an orderly way; and when we observe the order in given cases, or sets of cases, we speak of the "laws of nature." But as there are few scientific terms so constantly used, and abused, we had better look at it closely.

We can scarcely speak of a "law of nature" without thinking of human laws and lawgivers; nor can we well forget that laws are alterable, lawgivers change their minds, laws come into force on certain dates and cease on other dates. In all such respects as these there is *no resemblance whatever* between human laws and lawgiving and what we call the laws of nature. The laws of nature derive their existence and their efficacy in quite another way; for they are but the internal and necessary tendencies implanted in the material elements of the universe by its author; these internal tendencies are not something variable, foreign or superadded to the beings in which they are found, but are identified with and constitute the permanent natural properties of material beings. That is the first point to keep in mind, and it shows that the term is only a metaphorical one. Scarcely less important is the fact that we apply it, indiscriminately, to all manner of so-called laws, which are totally unlike.

How we apply the term "law of nature" to so-called laws which are totally unlike

Twice two, for instance, is four. This is not a law of nature. It has nothing whatever to do with nature's events, nor their mode of occurrence. Whatever the interactions and transformations, evolutionary and otherwise, of ether and energy may be, such a law as this of arithmetic throws no light upon them, expresses no part of them, and is wholly independent of them. Such laws as these are not "laws of nature" in the usual scientific sense of that term. They are not physical laws at all, but properly metaphysical laws, and independent of any contingent events or conditions. What we call the laws of nature may apply, at best, only to our little portion of time, only to our little portion of space. But the laws of thought, the fundamental principles of logic and mathematics, remain. The external world does not matter to them, they are wholly independent of it. Chaos might supervene, the laws of gravitation and motion and life might all disappear, and the propositions of logic and arithmetic would be just as true. They are true because they correspond with the relations between universal, abstract ideas, and not with concrete or particular facts or circumstances. Four involves and contains the idea of twice two, and that is enough. The truth of the other so-called "laws of nature" and our theories of her working does not primarily depend upon the logical and reasonable character of our theory — though that is necessary if we are to be justified in adopting it — but first and foremost upon *the correspondence between the theory and the facts.*

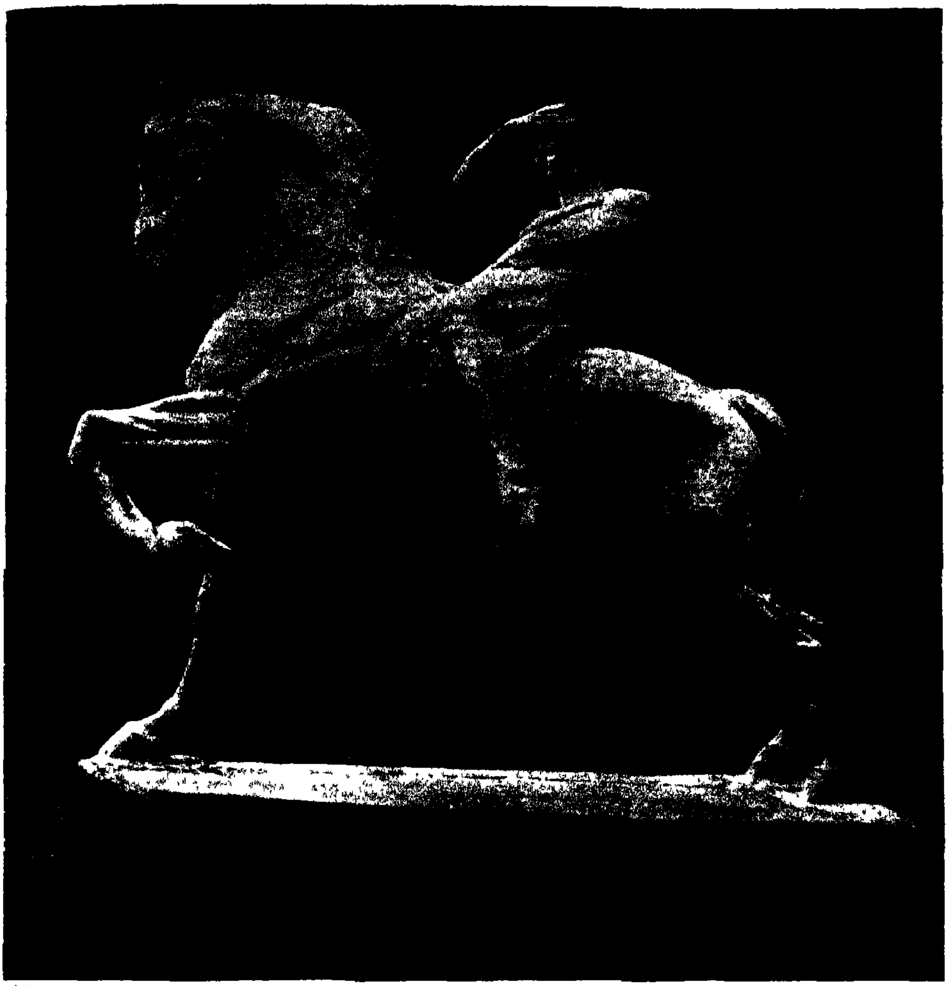
The false theories which strew the path of the scientist

The records of science are strewn with false theories which were beautifully consistent with themselves and read most convincingly, but failed to correspond to the facts. Since we are rational beings, we all love a beautiful theory, but we have to beware lest the beauty of our theories blind us to the facts, by which, in the last resort, the theories will be judged. Nothing could be more beautiful, consistent, appealing, than Lowell's theory of Mars, but no one knows better than its supporters that this theory must ultimately be judged by the facts, not by its internal consistency. Nothing could be more magnificently satisfying to the mind than Newton's law of gravitation, but Newton waited many years before publishing it, because the inaccurately recorded facts before him did not tally with the law. Lesser men would have made the facts square with the theory. Newton kept the theory in abeyance until he was satisfied that it squared with the facts.

Mathematics — including geometry — long called the "queen of the sciences," does not enter into our present scheme. Here we recognize the existence of this noble science, and acknowledge that, of all the descriptive sciences, astronomy owes most to mathematics, and will owe more in the future. But having done so, we must insist that it is not for mathematicians to impose their conclusions upon the existing world. Mathematics is an abstract science, its laws are absolutely certain and immutable, because they are all necessary, and could not be otherwise. But this does not mean that all the deductions of mathematicians are equally certain and immutable; for mathematicians start out with certain *assumptions* about nature, argue therefrom in their inimitable fashion, and then come to such and such conclusions.

"The cradle songs with which the teacher lulls his pupils to sleep"

The observers of nature are constantly discovering that these conclusions are wrong, because the original assumptions were imperfect. "Hypotheses," said Goethe, "are the cradle-songs with which the teacher lulls his pupils to sleep." Again and again this has happened. Mathematicians have made this or that assertion about flying-machines, or the nurture of school children, or the distribution of stars, or what not, and have sought to silence all discussion, because they were justly certain of the validity of their logical processes, and then they have turned out to be wrong.



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PHYSICAL ENERGY — THE STATUE BY MR. G. F. WATTS FOR THE TOMB OF CECIL RHODES

Our formulation of those "laws of nature" to which alone the term should be restricted cannot hope to boast the certainty and the accuracy and the superb independence of the laws of thought, of logic, of numbers and the like. The students of nature — that is, of the physical universe — can only observe to the best of their ability, put their observations together, and state general modes of action, which may just as well be called the "habits of nature" as the "laws of nature." But our observation may be wrong, or at least incomplete, and if so we must hasten to correct it or to supplement and improve it.

The man of science, like the child, should admit his mistakes and correct them

The critics of science will continue to jeer, but the wise will know that science is therein the more honored. For it behooves the great scientist as well as the little child to admit his mistakes and to correct them when they are made manifest to him.

The lesson and the meaning of all this is that we must be humble We shall study the law of gravitation, the laws of planetary motion, the laws of motion in general.

Elsewhere we shall study the laws of life and death, the laws of health, and so forth. But these laws are so marvelous and complex, that rarely have we been able to gain a full insight into any one of them: and too often even men of science, as well as ordinary mortals, have been led to proclaim as final and irrefutable propositions which a deeper study has shown to be at best only partly true or only probable instead of absolutely certain. When men in the last century first completely grasped the mighty idea of the order of nature, they were far too confident in asserting this and that to be part of her everlasting laws, and far too ready to be content with accepting them, instead of humbly going on to question and to observe. Science has been too often discredited in consequence, and hampered in its progress.

The horrible nightmare that materialism sought to impose upon us

The nineteenth, the "wonderful," century already begins to be seen as not only a century of superb discovery, but also a century of many confident mistakes. Our almost immediate predecessors boldly announced laws about the nature of atoms, laws about the eternity of matter, laws about the dissipation of energy, laws about the origin of species, laws about universal evolution, and so forth, which we now know to be either doubtful or only half-true, or else wholly untrue.

Materialism was one of the horrible nightmares which men sought to impose upon mankind in consequence. The history of that degradation should give us pause. Here let it be set forth in words the clearest and most conspicuous that this kind of insolent dogmatism, never surpassed by ecclesiasticism at its worst, is not for us. On the contrary, we here recognize that the sum of all finite things may be divided into two parts, one involving the perfections of life, which in its highest form we call "mind," the other not thus endowed — the psychical and the physical universe respectively. The physical universe we have summed up in a brief list of two items only, ether and energy. What we call the "laws of nature" are there concerned. What we call "astronomy," old or new, is concerned ultimately with large-scale doings, changes, and interactions of ether and energy. We call this section "The Universe," and the students of the physical sciences are content to assume that what they deal with, if they could only probe it deep enough, is the sum total of what we have called the "physical universe."

Two really distinct and equally real orders of objective existence

But be it here most solemnly stated that we acknowledge the existence of another order of reality, no less objective, which we call "psychical." Though we boast that we deal with the universe, it is only one of its two intimately associated parts that we shall consider in this section. The world of mind and thought and feeling, with its laws, its breadth and depth — that is outside our present purview. Physical science has never answered the arguments which prove that the psychical is a higher order of reality than the physical: that matter left to itself can never attain to the most elementary form or act of a living, sentient, thinking being. Such activity requires a higher principle than any combination, however complex, of ether and energy.

Life more than a chemical reaction, thought than a ripple in gray matter

Life is far more than a chemical reaction between highly organized molecules; sensation is something surpassing the vibration of a set of fibers, thought is more than a ripple in the convolutions of gray matter. Just what these perfections are in themselves does not require discussion or determination here; that is the proper sphere not of astronomy or physics or chemistry but of philosophy, more especially of psychology and its allied studies. We have mentioned them in order that our enumeration of the ultimate classes of beings in the universe might be quite complete, and to afford something of a suitable setting for the other parts of this work.

EARTH'S AUTOBIOGRAPHY

The Rocks which are as Enthralling as a Novel if we Know how to Read Them

LIFE-STORIES SEALED UP IN PAST AGES

SEDIMENTARY rocks are plastered over the surface of the globe, making all together a layer fourteen miles thick. Fourteen miles of rock are not laid down and raised up in a day, and probably required at least ninety million years for their making. The question arises: Can we divide this immense coating of rock into layers according to their time of deposit?

Naturally and necessarily, the lower strata must, on the average, be the older, and the upper strata must be the newer, but we must not assume, simply because a stratum is on the top, that it has been recently deposited. It may have been extruded through newer rock by volcanic forces, or many newer strata may have been worn off it. Nor can we estimate the age of a stratum from its mineral character. The deposition and elevation of strata has never taken place simultaneously all over the globe; there never was a universal deluge; and America may have been down when Europe was up. Further, even if sedimentation had taken place simultaneously in different seas, and had been simultaneously raised as land, it might yet show very different mineral characters.

No doubt the minerals of the original surface of the globe were variegated, and, accordingly, even the same sheet of sediment may vary in character in different parts of its area. We may find strata six layers deep here, and six layers deep there, resembling one another in their mineral characters, and yet they may be of quite different ages. We may find strata six layers deep here, and six layers deep there, differing from each other in mineral characters, and yet they may have been laid down in the very same identical eras.

Neither from likeness in mineral character nor from likeness in serial position can we assume that rocks are of the same age; and neither from unlikeness in mineral character, nor unlikeness in serial position, can we assume that they are of different ages.

Again, how are we to divide stratified rocks into consecutive layers, each denoting a separate period of deposition? We find stratified rock of a certain depth, but how are we to say whether it was all laid down at one time, or whether it is the product of several different eras? If one stratum be laid on a puckered stratum whose puckers show evidence of wear and tear, it is safe to say that an interval elapsed between the depositing of the former and the depositing of the latter; but in many cases, no doubt, strata belonging to different eras lie continuously and without disturbance upon one another, exhibiting perfect "conformability" — the technical term — and show no division mark to denote their separation in time. The difficulty of separating and arranging strata is greatly increased by the fact that only here and there can we see their edges, and that, as a rule, only a few edges are visible. Even in the Himalayas, and in the Grand Canyon of the Colorado, where great numbers of strata are thrown open to view, we have by no means a complete series. As somebody has said: "We are very much in the position of persons called upon to describe the cloth in a warehouse in which they are allowed to finger only the edges of a few bales."

How, then, are we to draw lines and fix dates? The problem was solved more than a hundred years ago by William Smith, often called "the father of English geology," a canal engineer, who, in the exercise of his profession, had many opportunities of studying cuttings. As a result of them, he formulated the principle that strata must be placed in space and time *according to the fossils they contain.*

Fossils are organic remains of plants and animals, preserved in rock, or imprints of organic bodies in rocks. Fossils may be of all kinds and sizes. The skeleton of the mammoth with hair and flesh still adhering, the track of a worm marked on sandstone or shale, the sharks' teeth in the deep-sea ooze, are all fossils.

The signs of life that are preserved in the ocean beds

In the soil and on the surface of the earth most organic substances decay, and leave almost no residue, but in the bottoms of lakes, in bogs, in rivers, in mineral springs, and in the sea they may be protected in various ways from destructive agencies, and retain their shape, at least, for tremendous periods of time. The sea-floor, and particularly the sea-floor near the shore, is especially likely to preserve organic remains in its constantly accumulating sediment; and it will preserve, of course, not only organic remains native to the sea, but also organic remains proper to the land that have been brought down by the rivers. Accordingly, since the sedimentary deposits were probably laid down on the sea-floor within a hundred miles of shore, it is not surprising that they contain numerous fossils.

When we examine the fossils thus preserved in strata, we find that lower and higher layers contain different fossils, and that they are graded in a regular order as we ascend. We find that all over the world fossils occur in this regular order, and that it is possible to divide strata accordingly, placing any sedimentary rock in its proper position if we know what characteristic fossils it contains. It is the fossil, more than the mineralogy of the rock, that tells its geological age.

The various attempts to classify strata, and the names now in common use

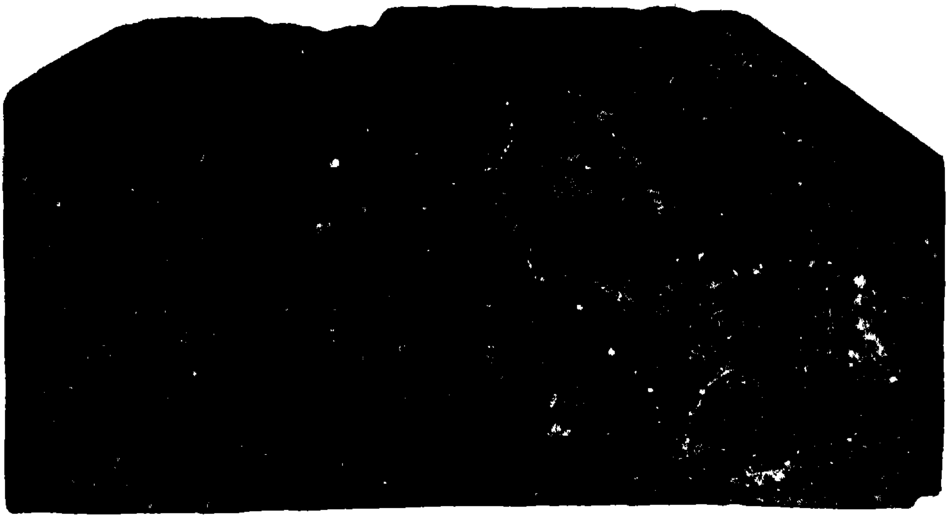
The use of fossils for this purpose depends on the two very important principles laid down by Smith: one that the strata are *normally* found in the order of their deposition, the oldest at the bottom and the newest at the top; the other that there has been a general upward progression in the grades of life on the globe which makes it possible to assign the period in life development to which a fossil belonged.

Before William Smith enunciated these principles there had been various attempts made to classify the strata, and a variety of terms had been used to indicate comparative age: Primary, Secondary, Tertiary, etc. Later lithological characteristics were used as the basis of classification: — Carboniferous or coal age, Old Red Sandstone, Cretaceous or chalk age, and so forth.

But introduction of the life element, with its more definite definition of geological periods, necessitated the adoption of some new names. Sometimes they are geographic — Permian, from Perm in Russia; Devonian, from Devonshire in England — from the district where the study was made. The following table gives the names as commonly used in America for the main divisions and their principal subdivisions:

Period		Fossil
Cenozoic	Quaternary	
	Recent	
	Pleistocene	Man
	Glacial Period	
	Tertiary	
	Pliocene	"Java-man"?
	Miocene	
	Oligocene	
	Eocene	Mammals
Mesozoic	Cretaceous	
	Jurassic	
	Triassic	Reptiles
Palæozoic	Permian	Amphibians
	Carboniferous . .	Fish
	Devonian	
	Silurian	Invertebrates
	Cambrian	
Proterozoic	—	
Archæozoic	—	

ALIVE IN THE DAYS BEFORE MAN CAME



Courtesy American Museum of Natural History

A COLONY OF TRILOBITES

The upper picture shows a group of trilobites, curious little extinct crab-like animals, whose fossil bodies are found in rocks of the Paleozoic age in most parts of the world. These came from Niagara shale at Lockport, N. Y. The lower picture is a much enlarged photograph of three individuals.

The igneous rocks of the Archæan formation which contain no fossils

Under the sedimentary rocks we find igneous crystalline rocks, known as the Archæan formation, which are almost certainly volcanic in origin, and have probably either burst through the original crust or flowed out through a fissure in it. Before the Cambrian period there was a tremendous outflow of melted rock, covering the Lake Superior basin, and building up a series of volcanic rocks 20,000 feet thick. In the Mesozoic period there were outflows that covered the Deccan in India to a depth of 4000 or 6000 feet. In Tertiary times 200,000 square miles in Idaho, Oregon and Washington were covered to a depth in some places of 4000 feet. In such a way, and by more localized volcanic action such as we see in modern volcanic explosions, the Archæan rocks were made; and we have no knowledge of the real original crust of the earth beneath its load of cinders and mud.

In the Archæan rocks no fossils are found, but there can be little or no doubt that during the Archæan period low forms of life did exist. We do not know how life began, or when it began, but it certainly began ages before the Cambrian period, for the animals found in the Cambrian deposits represent quite an advanced stage of animal evolution.

That life did not exist is not to be inferred from lack of fossil remains

In the vast sedimentary deposits below the Cambrian rocks no fossils have been found, but there can be little or no doubt, nevertheless, that in the periods represented by these deposits there must have been multitudes of invertebrate animals in the world, for, as we have mentioned, the animals found in the Cambrian deposits represent quite a high development.

The Palæozoic period is the era of Mollusca, Crustacea, and some strange fishes and amphibians; the Mesozoic period is the era of reptiles; and the Cenozoic period is the era of mammals.

Let us now take a general survey of the three great fossiliferous geological periods.

Where the oldest of all the fossils in the earth are found

The first period. In the Cambrian rocks of the first or Palæozoic formation period the oldest known fossils are found These consist chiefly of shell-bearing molluscs and of highly organized creatures such as water-fleas and trilobites, but there are also to be found a few sponges, worms, and water-plants. Trilobites are perhaps the most characteristic fossil of the primary strata. They seem to bear a resemblance to such extremes as the king-crab and the wood-louse, and have a three-lobed appearance — from which they take their name — and several pairs of slender legs. Some are blind, and some have huge eyes. Some are almost microscopic, and some are almost two feet long.

The first record we can find of a special organ of vision

One of the common features of all trilobites is the possession of a head-shield which, except in some blind genera, bears a pair of large compound eyes. In some the eye is more or less conical, and in others it is crescent. Several types of eyes of very complicated structure have been recognized. In some the eyes have fourteen lenses only, while others have as many as fifteen thousand. The eye of the trilobite is the first record we possess of the presence of a special organ for the perception of light, and we see what a wonderful and complex organism it is. These animals by virtue of size, number and activity, most probably ruled the animal world of their day. According to the general opinion of present-day zoölogists, the trilobites are not crustaceans, as was formerly believed, but are related to the arachnida, a group to which scorpions, spiders, and mites belong.

The greatest extent and depth of Cambrian rocks is found in Wales, and the deposit which was made was no doubt drained into the sea from a land to the west.

In the Silurian strata we find great numbers of molluscs and crustaceans, also sponges, starfish, sea-urchins, and foraminifera.

THE REAL RULERS OF THE AMERICAN WATERS IN THE CRETACEOUS DAYS

Some of these strange creatures that lived in the sea millions of years ago reached a length of 75 feet or more and had, like snakes, rows of formidable teeth in the roof of their mouth used as weapons for seizing their prey. The saurians and sea serpents, says Professor Geikie, were the real rulers of the American waters in the Cretaceous Age

Here, for the first time, fishes appear – strange fishes with no bony skeleton, with no lower jaw, and covered with a kind of plate armor. Fossil ferns and lycopods also are found, and a scorpion with a poison gland and sting, also a true insect wing. The fact that the scorpion has a sting proves that there must have been other land animals to sting.

The Devonian and Carboniferous strata are characterized by luxuriant land vegetation, and a large number of insects and crustacea. In the Carboniferous era most of the great coalfields were formed, and it is probable that at this time there was an excess of carbon dioxide in the atmosphere which increased the temperature and favored vegetation, so that ferns and club mosses grew to a great size.

Among the insects in the tropical jungles were ancient forms of spiders, millipedes, centipedes, mayflies, cockroaches, crickets, beetles, moths, and butterflies. Scorpions of gigantic size also abounded. In the seas and lakes were many fishes. But the most interesting animal fossils of this period are strange amphibians rather like lizards or salamanders, with long tails and weak limbs. Some of these are only a few inches long, others are seven or eight feet in length.

In this period, also, in the Permian strata, the first reptile is found — the Proterosaurus.

The second period. The rocks of the second or Mesozoic period contain the records of nature's experiments in reptiles. No other strata contain such grotesque and monstrous forms. Here we find the iguanodon, a lizard-like animal about thirty feet long, that walked on its hind legs, and had a powerful muscular tail like a kangaroo. Its teeth and bones were first found in England, but no less than twenty-nine iguanodons were found in a colliery in Belgium. Here came the plated lizard, or Stegosaurus, the amazing Brontosaurus, fifty-five feet long, and seventeen feet high, and twenty tons in weight, with the smallest head in proportion to its body of any animal known. Here came Diplodocus, eighty feet long, with an enormous neck and an equally enormous tail. In the Cretaceous rocks of western North America reptiles are particularly abundant.

According to Professor Geikie, the real rulers of the American Cretaceous waters were the pythonomorphic saurians and sea-serpents. "Some of them attained a length of seventy-five feet or more. They possessed a remarkable elongation of form, particularly in the tail, their heads were large, flat, and conic, with eyes directed partly upwards. They swam by means of two pairs of paddles, like the flippers of the whale, and the eel-like strokes of their flattened tail.

IN THE DAYS WHEN THE FOSSILS WE FIND IN THE ROCKS WERE SWIMMING IN THE SEA

"Like snakes, they had four rows of formidable teeth on the roof of the mouth, which served as weapons for seizing their prey But the most remarkable feature in these creatures was the unique arrangement for permitting them to swallow their prey entire, in the manner of snakes Each half of the lower jaw was articulated at a point nearly midway between the ear and the chin, so as greatly to widen the space between the jaws, and the throat must, consequently, have been loose and baggy like a pelican's"

Equally monstrous were the huge turtles, some of which measured more than five yards across between the tips of their enormous flippers

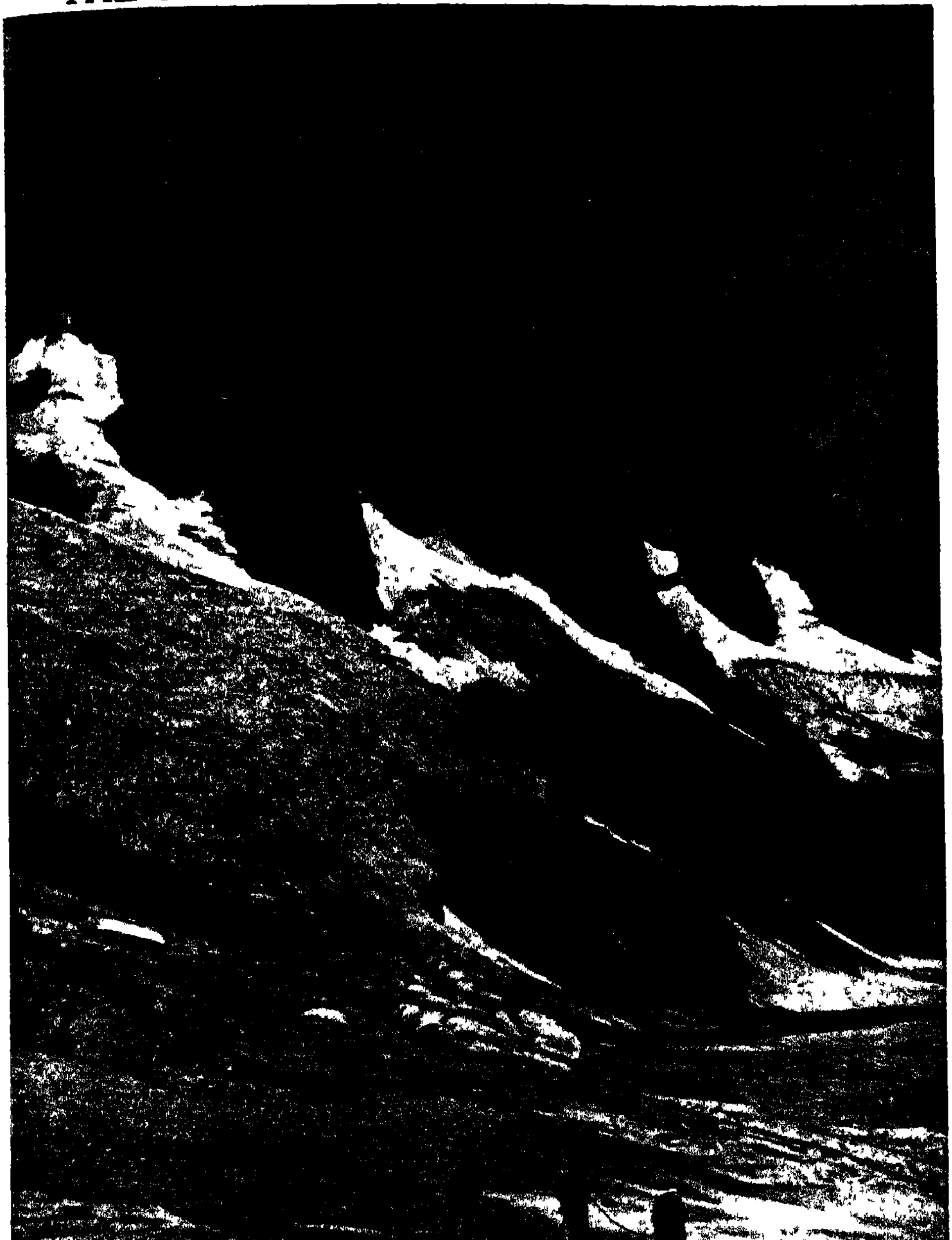
And even more monstrous were the bird-lizards, or pterodactyls – lizards that flew about like bats, and in some instances measured twenty feet between the tips of their wings It must have been a strange, weird world then!

But not all the fossils of the Mesozoic formation were remains of monstrosities, for in this era appeared the first true birds and the first true mammals The oldest bird known, the Archæopteryx, was rather smaller than a crow, it had a long, lizard like tail, its wings had free claws, and its jaws had teeth The first mammals were small, and belonged to the same types as the kangaroos and opossums, and moles and shrews, and duck billed platypus.

THE COAL FORESTS OF MILLIONS OF YEARS AGO — AN IDEAL PICTURE OF THE CARBONIFEROUS AGE

In the Carboniferous era, most of the great coal fields were formed and this is how a "coal forest" must have looked Fossil trees are still found standing in coal seams, proof that a coal field is an old forest, and not merely vegetable matter washed down

THE ADAMANTINE TOPS OF THE EARTH



From a photograph by Donald Macleish

THE NEEDLE PEAKS OF THE GRAND CHARMOZ, TO THE EAST OF CHAMONIX, SWITZERLAND

Perhaps the most characteristic fossils of the Mesozoic formation are the ammonites (so called from their resemblance to a ram's horn) and belemnites (like arrowheads) — shells of certain molluscs. Sponges also swarmed on the floors of the Cretaceous seas, and the flints found in limestone are products of these. Among other insects, dragonflies, mayflies, cockroaches, beetles, and butterflies are found. The vegetation in the Mesozoic period was luxuriant. Ferns, club-mosses, horsetail reeds, cycads abounded, besides oak, willow, fig, walnut, plane, laurel, beech, maple, magnolia, and other trees.

The third period. In the Tertiary era there were tremendous upheavals of the sea, and most of the great modern mountain-chains were made. Not only were Cretaceous deposits raised into low lands, but "from the Pyrenees to Japan the bed of the early Tertiary sea was upheaved into a succession of giant mountains, some portions of that seashore now standing at a height of at least 16,500 feet above the sea."

Almost all the big weird reptiles have died out; and it is now an age of big mammals. Not only have the monstrous reptiles died out, but all animals, large and small, have changed, and have come much more to resemble the animals of modern times. Still, however, monsters that have not survived to present days continue to be produced. Among these were mastodons, mammoths, saber-toothed tigers, and tortoises six feet long. In the Miocene deposits apes are found. The vegetation of this formation is tropical or sub-tropical.

When New England was lost under ice nearly a mile thick

The Pleistocene era of the Quaternary sub-division of the Cenozoic period is also known as the "Glacial Period," since at this time a large part of the temperate zone was covered with ice.

In Europe alone nearly 800,000 square miles were hidden under the mantle of ice of enormous thickness, the depth reaching 6000 or 7000 feet in Scandinavia. In North America it was mainly the northeastern half, the lowlands and not the mountainous parts, that was buried beneath the continental glacier. This glacier was the result of three great centers of ice accumulation and radiation, spreading over four million square miles. All Canada was covered and the ice sheet extended into the middle flat part of the United States as far as southern Illinois and in the east as far south as New Jersey. According to LeConte the thickness of the New England glacier was probably 6000 feet and surely not less than 4000 feet. These huge masses of ice moved in glacier fashion, grinding and scratching as they went. The soils were pushed away, the rocks abraded and eroded, and the valleys deepened and widened. During the glacial period various land areas subsided under the sea and were again elevated.

The laying down of the fossil beds in different countries

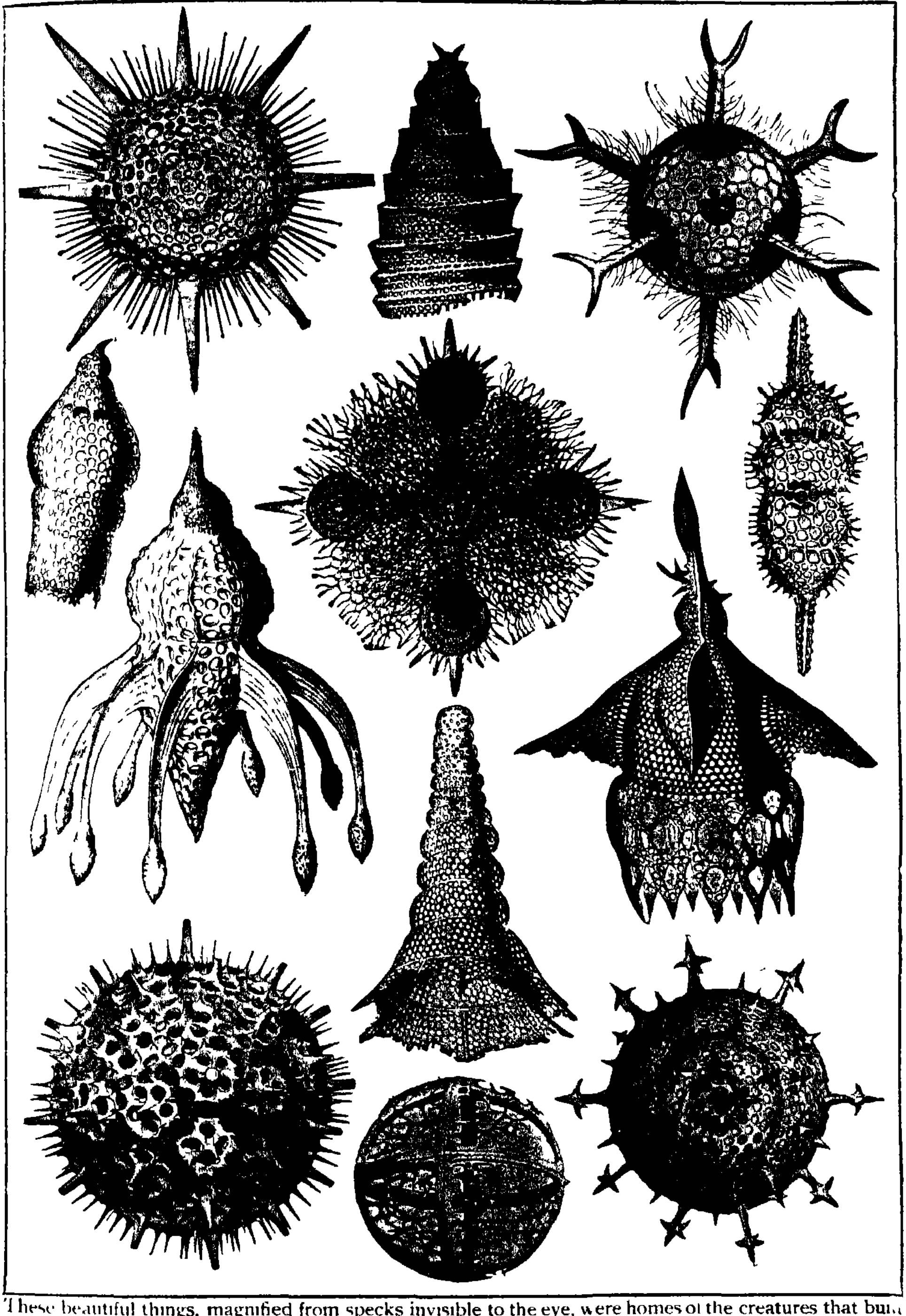
When the ice was at its height no doubt all the northern vegetation was killed, and all the animals of the northern hemisphere migrated south. The musk ox roamed as far south as Kentucky, and the arctic foxes found a congenial climate in the Pyrenees.

As the climate became less severe, elephants, mammoths, hippopotamuses, woolly rhinoceroses, lions, bears, boars and bisons appeared in Europe, but their reign was short. In caves in the Dordogne, in France, and elsewhere, bones strewn on the ground have been found; and the carvings of some of the bones show that the cavemen hunted and ate the mammoth, the reindeer, the elk, the horse, and the bison.

We have spoken of the glacial epoch, but there were really several glacial epochs — some say three, and some seven — with more genial periods between. Man must have lived in this epoch, but few traces of him have as yet been found — a few skulls and jaws, and flint weapons.

When we consider the great geological epochs, as described by the fossils in the sedimentary rocks, we must not make the mistake of supposing that all rocks containing the same fossils were laid down and raised up at the same time.

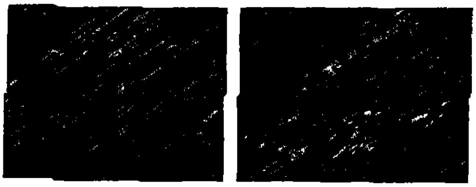
FORMING A NEW LAYER OF THE EARTH



These beautiful things, magnified from specks invisible to the eye, were homes of the creatures that built them. Inhabiting the sea in untold billions, they die and accumulate in thick layers, forming limestone, which may one day be dry land in which some geologist of the future will find fossils of our time.

In any part of the world the fossils in any superimposed series of formations have a definite serial relation to each other, but one cannot say that similar fossil beds in different countries were laid down contemporaneously. Rather the reverse, for, since each form of life probably sprang into existence in some particular region, it must have taken time for each to spread to other regions.

All these depositions and elevations of sediment that produce the different formations, with their fossil contents, necessarily imply constant changes in the geographical formation of the earth.



THE MARVELOUS PRESERVATION OF STRUCTURE

The first of these two photomicrographs shows a piece of wood a few years old; the second, a piece of coal millions of years old. Under the microscope the structure of one resembles the other in a remarkable way, showing astonishing preservation of delicate structure, through countless ages, deep down in the pressure of the earth.

Among palæozoic lands was the palæozoic continent known as "Gondwana Land," which consisted of South Africa and a large part of Central Asia, together with Madagascar and the Indian Peninsula; and it is quite possible that "Gondwana Land" joined to ancient South America through a continent in the South Atlantic, known as "South Atlantis." If this were so, one might have gone by land in those days from India to Peru; but not a single mammal or flower would one have seen the whole way, only a few strange monsters and reptiles lurking in the primeval jungles that covered the land.

A PIECE OF ROCK FROM ANOTHER WORLD

This photograph is of a piece of rock that has fallen on our earth as a meteorite, which proves on analysis to contain no element not already found in the rocks of the earth's crust

China, Mongolia, and eastern Siberia are also of palæozoic date, and formed a continent known as "Angaraland," and at this time the North Atlantic was probably occupied by a great continent — "Atlantis."

In early Mesozoic times there was a great sea named the "Sea of Tethys," the ancient Central Mediterranean, between Gondwana Land, Angaraland, and the European part of Atlantis. Towards the middle of the Mesozoic times the bottom of this great sea heaved up and formed Asia Minor, the mountain regions of the Hindu Kush, the Pamirs, the Himalayas, and the Trans-Himalayas, thus completing the continent of Asia. The modern Mediterranean is a relic of that mighty sea.

At the end of the Mesozoic period, also, North America emerged from the sea. In the Cretaceous period it was covered by the sea from the Gulf of Mexico to the Mackenzie River, and perhaps as far as the Arctic Ocean; and when the ocean bed rose, a large inland sea, known as "Lake Laramie," was left in the center of the new continent.

Even in Quaternary times, when prehistoric man was chipping his flints, the world's geography was very much unlike its geography now. In these days Europe extended far westwards of the British Isles; and the Irish Sea, the English

Channel, and the German Ocean were wide valley plains watered by noble rivers. The Rhine, with its tributaries the Elbe and the Thames, flowed northwards and opened into the sea near the Faroe Isles, and the Seine flowed along the valley of the English Channel, to enter the Atlantic a hundred miles west of Land's End. There was no Adriatic, and the Mediterranean was divided in two by a belt of land which stretched across from Africa to Europe. Asia was probably united to America across the Behring Straits, and Europe was perhaps still united to North America by Atlantis.

But perhaps nothing gives us a better idea of the protean changes in the surface of the globe than a comparison of the geography of North America at different epochs. In the early Carboniferous times of the Palæozoic period the northeastern shores of our continent probably extended somewhat further into the Atlantic than at present; and on the south what is now the Gulf of Mexico probably covered the area now occupied by the whole of Florida, Mississippi, and Louisiana, as well as a part of Virginia, the Carolinas, Georgia, Alabama, and Texas. It is also probable that the Pacific then occupied a considerable portion of the country east of the Rocky Mountains, from Mexico to the high north. It is possible indeed, that nearly all the Rocky Mountain country was at this time below the level of the sea, and thus the continent, as a whole, lay somewhat to the eastward of its present position.

In the Triassic times of the Mesozoic period a good deal of flat land whereon the coal-measures were laid down was wrinkled into great mountain folds, and the Rockies began to appear. All the great chain of the Alleghanies lying to the west of the old Blue Ridge, and extending from near Albany, N. Y., to Alabama, was about this time thrown into mountain folds, the higher summits of which rose six or eight thousand feet above the sea. These foldings took place also in the region of the Gulf of St. Lawrence.

During the Cenozoic period there appears to have been no great development of mountains, but the continent underwent a general uplift which brought it nearly to its present form. It is probable that the great strait connecting the Gulf of Mexico with the Arctic Ocean was closed at this time. Most of the lowland district of the Atlantic and Gulf border, and the belt of country along the coast were still under shallow water.

THE WORK OF FIRE AND WATER — VOLCANIC ROCK THAT HAS MADE ITS WAY THROUGH THE CRUST

Many of the archæan rocks we know are volcanic in origin; and this photograph shows how fire-formed rocks crept through the original crust, or flowed through a fissure, in the days when continents were being laid down. The marks on the sandstone to the left were made by the sea in prehistoric times, so that here we see the action of fire and water side by side.

LIFE BUILT UP BEFORE OUR EYES

This astonishing photograph shows, 40,000 times bigger than they really are, a colony of living cells, each one of which is reproducing itself by dividing into two, which divide into four. All cells of living creatures are derived by development from a single cell. These cells, photographed by Mr J J Ward, represent the lowest kinds of green plants — the organisms which often produce the slipperiness of rocks in moist places.

LIFE REPRODUCES ITSELF

The Marvelous Processes by which the Living Cell Divides, Multiplies and Builds up Every Living Race

THE SUPREME MIRACLE OF THE WORLD

LIFE persists and excels itself, but all living individuals die or lose their individuality in their progeny as in the case of the amœba. All individuals being mortal, the maintenance and the destiny of all living species depends upon the capacity of the individual, before it dies, to reproduce itself, or leave some living remnant or minute epitome of itself from which will be again produced a creature to replace that which is gone.

It has been suggested that, on other worlds, life might embody itself in permanent continuous forms, and that, for instance, the markings on Mars might be due to one persistent, straggling, undying body of life. But we are dealing with life on earth and on the earth, at any rate, and for reasons which we can begin to divine, the continuance of life is in a tissue of births and deaths.

Individuals may persist for amazing periods. We may find giant tortoises which are centuries old, and trees which are thousands of years old, but we find that they die at last, and we have only to examine them in order to find that they were constructed—tree, day-fly, long-lived or short-lived—not wholly, if even primarily, for themselves, but for reproduction, for parenthood, and the future.

Of the many modes of reproduction the following may be mentioned: first, simple fission in which the individual simply splits into two equal parts and each part becomes a new organism as is exemplified by the amœba; second, a portion of the organism consisting of many cells is developed for the purpose of producing a new individual, as is seen in the runner of the strawberry or in the gemmule of the fresh-water sponge; third, among algæ and fungi and even among the higher plants a specialized cell, an asexual spore, is produced which unaided can produce a new plant; fourth, special cells, called gametes or sex cells, are produced of which two must fuse to form a single cell which thus acquires the power to give rise to a new individual; and fifth, that peculiar mode in which a female without coöperation of the male may give rise to young.

No matter which of these modes is followed in any case the individual animal or plant yields a portion of itself, which is sometimes more though never less than a single cell, and from that portion the new individual is formed. Every living individual is either, as some are, a single cell from first to last, or else, as all the higher forms are, a multitude of cells developed directly or indirectly from a single cell. Thus even the many-celled animals and plants, including ourselves, are single-celled in the first period of their life. Here is a problem, evidently, for we have to explain how the single cell becomes an oak or an elephant or a man, and that is the great vital problem called "development."

But we shall never answer the questions of development unless we begin at the beginning, and there is enough here to engage us for many a long day. We must not attempt too much at once, for we are dealing with the most complicated and difficult subjects of all imaginable inquiry. Even the human brain is simple compared with the problems presented by a microscopic cell which develops into a man, brain and all.

The first general fact of reproduction is its extent and its insistence

Therefore, we must definitely leave development out of the question at present, as writers in the past have too often declined to do, and we must try to find the facts of these cells from which new individuals grow, and which are in themselves the new individuals at the earliest stage of all the many stages between their begetting and their death.

There is ample material to study: birth and death are on every hand. Indeed, the first general fact of reproduction is its extent and its insistence. Over-production is the keynote, the ruling principle, of the living world. It seems to involve the most unheard-of waste, yet it is the definite and constant rule, and we have good reason for believing, from all manner of other evidence, that economy of means, and waste of nothing, is no less a principle of life. The truth is that this apparently insane and purposeless excess of reproduction, which leads living beings to form thousands and millions of cells, sometimes millions a year, each one designed to grow up into a new individual, and not one in millions succeeding, is not really wasteful if we look at life as a whole. The countless eggs of the fish which never reach maturity are consumed by other fishes and inhabitants of the sea, and serve their lives.

A microbe that might grow into tons of microbes in one day

The immature members of almost any species, animal or vegetable, are the staple diet which maintains the life of other species. As regards any particular species, the lavish abundance of its reproduction seems utterly wasteful, but as regards the sum total of life there is in the long run no waste. The waste involved in reproduction is therefore more apparent than real.

The capacity of reproduction, if only there be nothing to interfere, and if food for the new cells to live and develop be available, is beyond all bounds. A single microbe, with a fair field and no opposition, could become sixteen million microbes in twenty-four hours.

Not that the necessary supply of food and oxygen, etc., could ever quite satisfy such a figure, but the observed rate of reproduction would correspond to such a figure if circumstances permitted. The microbe of cholera, which is capable of doubling itself every twenty minutes, might in the course of a single day become 5,000,000,000,000,000,000,000 microbes, with a weight estimated at 7366 tons but, of course, the conditions which would permit such development as this are not found in nature. One microbe has actually been observed to become 80,000 in twenty-four hours, and 20,000 injected into a rabbit have been found to reach the number of twelve thousand millions in a day.

And if we consider the rabbit itself in Australia, or the rat, or some new weed introduced into our own streams, or any other case where the potentialities of reproduction get a chance to show themselves, we find that a single pair of individuals will soon people a continent, or a single seed become the parent of a forest.

How life overruns the land and crams the sea with ever-increasing speed

Wherever reproduction gets its head, life overruns the land, or crams the sea, with inevitable and ever-increasing speed, for its method is that of geometrical progression — 1-2-4-8-16-32 . . . and millions in no time. It is only because there are so many living species, animal and vegetable, and such long-standing balance of numbers, on the whole, among them, that we do not realize the full measure of the reproductive pace, except in novel circumstances, where man's interference, or some other unusual factor, has altered the balance of nature, and given some species or other an open field for development.

This tendency of reproduction definitely involves over-production. The normal case, for any species, is that more, vastly more, new individuals are produced than can possibly find room for their development. Accordingly, they die, as a rule to form the food of some other species; or, at the worst, to serve the cycle of life by the decomposition of their dead bodies.

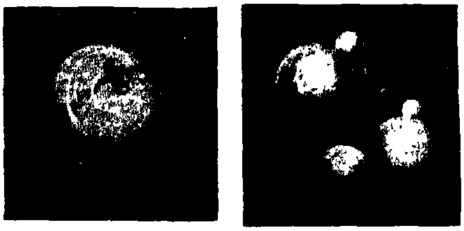
There is no ultimate waste, we thus see, and there is much possible gain, of a kind which has only lately been guessed. It was in great measure this fact of overproduction and his efforts to find a rational explanation for the same that led Darwin to formulate his theory of natural selection. If there be vacancies in your service for all the candidates, the duffers and the lazy will all get places, and your entrance examination is a farce. Just so, if there be food and room for all the young of a species, none will be rejected, and there can be none of that process of natural rejection, which is the more accurate name for natural selection.

The living cell from which every living creature comes

This over-productivity, normal throughout the living world, and without an exception, until we reach the case of civilized and very recent man, is therefore to be permanently kept in mind as an essential factor of one of the great molding forces of the living world.

Let us now look, if we can, at the details of the process which has such stupendous consequences and possibilities. It is an all-important step to have learned, thanks to the illustrious Harvey — still more celebrated for his discovery of the circulation of the blood — that, as he said, every living thing whose mode of reproduction is sexual is from an egg — *omne vivum ex ovo*. We can now, thanks to his beginning, make the statement more precise, and say that every living thing is derived from a cell. We concentrate therefore upon these cells, and ask their origin and history, and their relation to the individuals which bear them, and die, and leave them as a legacy to the future. We shall find very great contrasts between the simplest and most complex forms of the process of reproduction, but we shall find quite simple principles throughout. Above all, we shall find that the study of reproduction teaches us far more about the living cell, its structure and its nature, than we could ever learn about it by the study of cells which are not engaged in this extraordinary process.

Naturally, it is the one-celled creatures that provide the simplest case, too simple to teach us much. If we observe a microbe, a single-celled vegetable organism, which has no apparent nucleus, and almost no visible structure whatever, we find that it divides by what is called fission, or splitting. It really seems to live for this purpose, and we have seen that in twenty minutes or half an hour, under favorable conditions, one generation passes and is replaced by another. The little cell shows a sort of constriction at opposite sides or ends — as if an invisible string were being tightly drawn round it — and splits into two. It seems to be just a matter of convenience, for purposes of getting food and oxygen, that when the cell has reached its full size, and still wants to increase its life, it should split into two rather than grow incon-

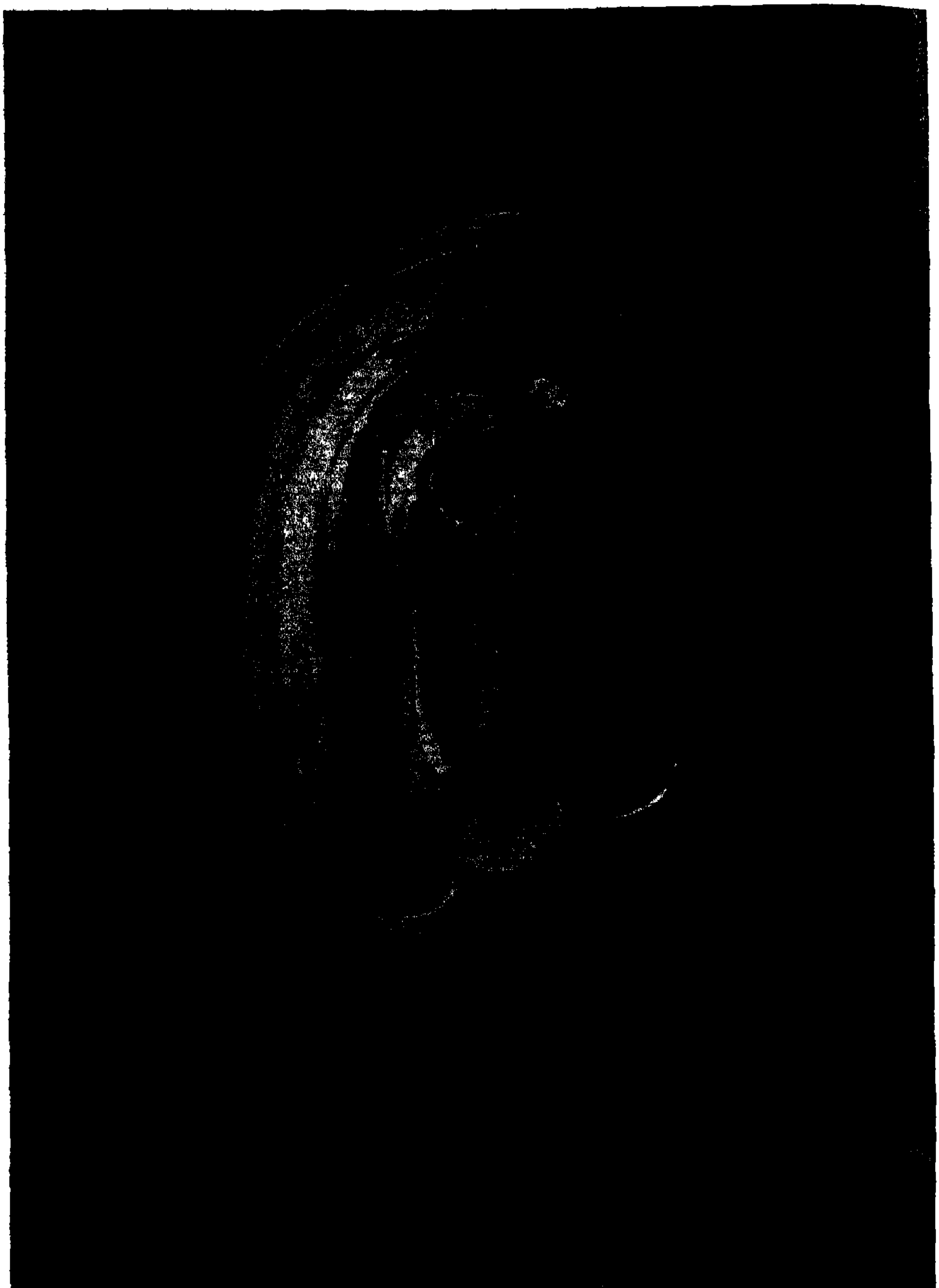


TWO METHODS OF CELL REPRODUCTION
The first of these pictures shows a cell about to divide by splitting
The second shows yeast cells reproducing themselves by budding.

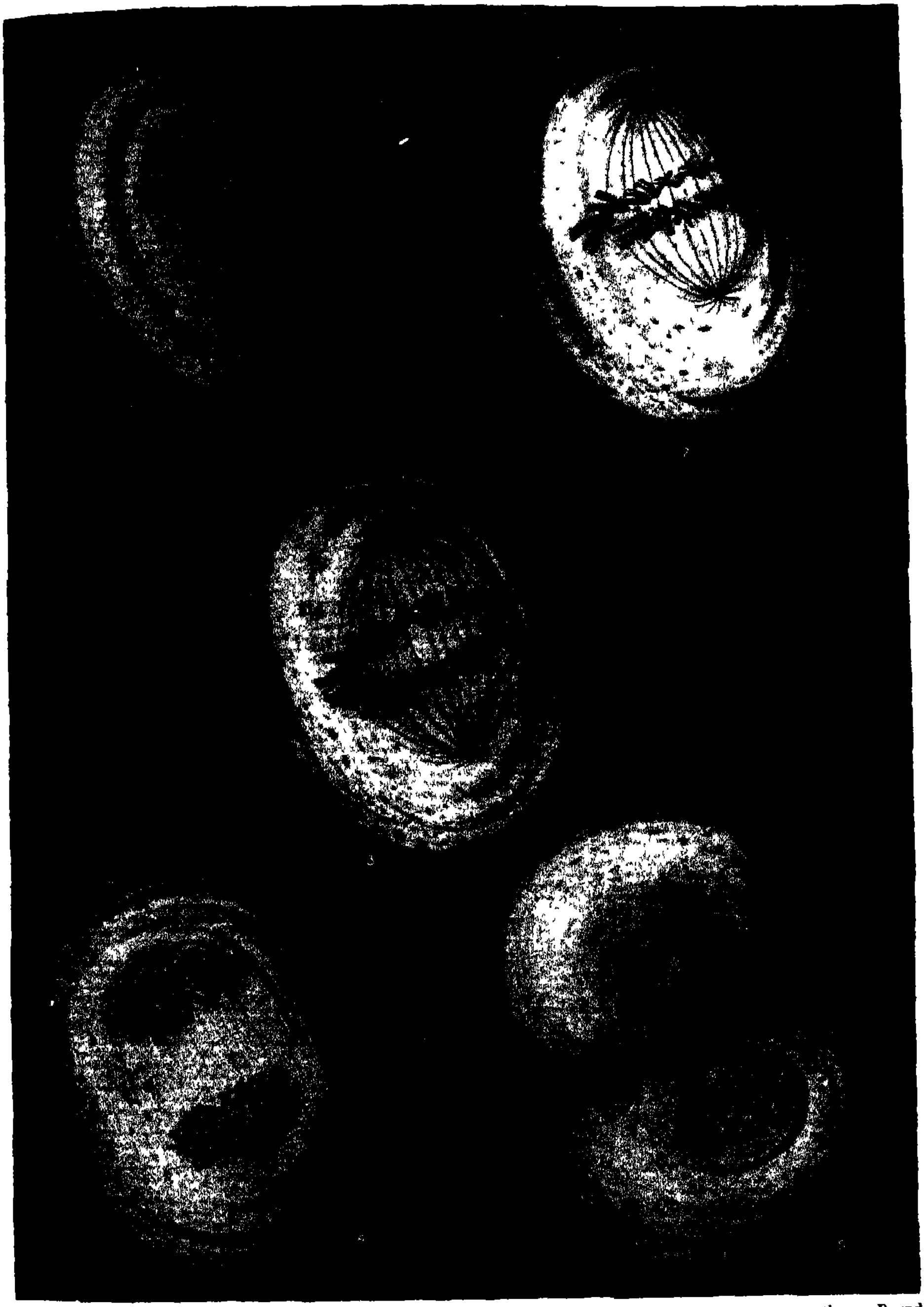
veniently larger. As to the details of the process, and the manner in which the constriction is brought about no satisfactory explanation has yet been found.

Reproduction of this kind is so remote from what we observe in the case of all but the lower forms of animals and plants, that we almost feel as if nothing could be learned from it. That, however, is not the fact. We here see that what we call the body in the case of higher forms does not exist. Among these creatures, individuals worth recognizing, having bodies of their own that die with them, do not exist. If we use Weismann's term of "germ-plasm," we see that the bacteria and similar forms are *all* germ-plasm — there is no body, and therefore no body-plasm with which to contrast the germ-plasm, as Weismann has so wisely taught us to do in the case of higher forms.

THE KEY TO ALL THE PROBLEMS OF LIFE



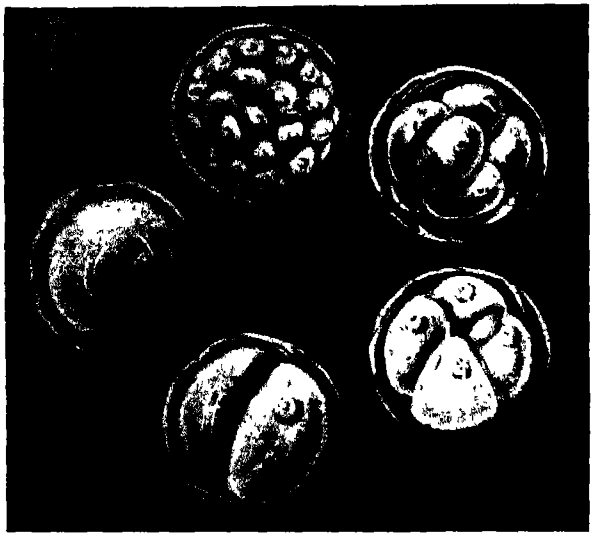
The living cell represented in these pages as the fullest powers of the microscope reveal it to us, holds the key to problems which have baffled men through all the ages. So small that ten millions of them could come into a single square inch, a single one of these cells has in it all the potentiality of life — of an oak, or a lion, or a Shakespeare. Every living thing is made up of cells similar to this, linked together into a continuous wall of tissue. On the right-hand page is an attempt to represent the very beginning of a living thing The large cell on this page may be called the mother cell. The right hand page shows how from this cell proceed daughter cells. In the first cell the nucleus is in its normal globular form, and its vital substance is arranged in loops, which are called chromosomes. The two black specks on the outer edge of the nucleus are called centrosomes, and here they are seen separating to opposite poles. In the



second cell the centrosomes have formed two opposing spheres of attraction, with fibers, in spindle form, connecting them. Round these fibers the chromosomes arrange themselves, and an amazing thing now develops In some mysterious way each chromosome is split lengthwise, with the result shown in the third cell, and the two separate themselves to the opposite poles, though still holding to the filament attached to the centrosomes The stage shown in the fourth cell is thus reached, and now occurs the supreme miracle of the living world, upon which life and all mankind depend. The fibers break in two, and each set of chromosomes becomes a separate nucleus The cell divides, and in place of the mother cell there remain two daughter cells, each in time to become also a mother cell. So these two multiply themselves, and so, from the beginning of living things till now, has all life been sustained,

The yeast-plant offers a good and familiar illustration of a mode of reproduction which is not quite so simple as fission, but which is removed from that simplicity by only a step. The yeast-plant is a round cell, which grows to its full size, and then, instead of splitting into two, forms a sort of bud, which at length becomes detached and constitutes a new individual. Sometimes we may see a series of such buds, of diminishing size, more or less attached to each other, and in a little while they will each be free and independent.

This is called reproduction by "gemmation," or "budding." It is a stage higher than fission, for in this case the parent can be identified, and survives the reproductive process; but, all the same, we see that there is not very much difference between the cell which splits into two and the cell which, instead, buds off somewhat less than one-half of itself.



HOW THE CELLS OF LIFE MULTIPLY

These pictures show the multiplication of the cells in a crab, and they are typical of all living things On the left is seen a single cell, which divides into two, which become four. So cell division goes on indefinitely — cells join together in a million ways and a living creature is in the world

The very astonishing fact has been observed that in some species which reproduce themselves in the simplest fashion, and in which there is no such thing as a differentiation of individuals to indicate sex, two individuals can nevertheless be observed to fuse and become one — just the opposite process to that we have been describing. This process is called "conjugation," and in these lowly forms we observe for the first time a phenomenon of life which is of scarcely less importance than cell-division, for here we have the simplest form of sexual reproduction, which consists of *the union of two distinct cells to form one* which is capable of producing a new individual of the species whether single-celled or many-celled, with rejuvenative powers to continue the race.

We shall learn that cell-division is served by cell-union, for among the higher organisms wherever there is sex, cell-union or conjugation involves the formation of cells which are destined to divide, and change as they divide and multiply, until we see before us the full-formed and infinitely complex body of a horse, an oak, or a man. There is thus some subtle fact of the living cell and its processes which expresses itself in a kind of balance between cell-division on the one hand and cell-union on the other. This we see in its completeness if we contemplate the sequence of events from generation to generation, in any of the higher forms of life. Two cells unite, as we shall see, and form one. This divides and forms billions in the body of the new individual. Of these billions some are so specialized that if one of them unites with a similar cell likewise specialized from another individual, or in rarer cases from the same individual, another new individual will be formed. The sequence of generations, the making, growth and destiny of successive bodies, is therefore a rhythm of alternating cell-union and cell-division.

Allusion has been made to a fact which is closely associated with reproduction and is thought to be an essential part of it, the fact of sex. We shall make no real progress with our subject unless we rid ourselves from the first of this almost universal and certainly very excusable

misconception. Observe that it was possible to describe unquestionable reproduction in the case of many efficient and successful and important races of living beings in which the methods employed are devoid of any semblance of sexuality whatever. Not only those such as we have mentioned, but many creatures, such as the amœba, are totally without sex.

But sex, and the relations of sex, and the different forms of the two sexes, their different functions, and all that this implies, alike for individual life and for reproduction itself — all this is totally absent in many species, and is to be looked upon as unquestionably a later development, a new complication, not essential in the life-history of all living things, which has been introduced into the process of reproduction.

Parthenogenesis or virgin birth as illustrated by the social bees

Thus what we have been describing hitherto all comes under the heading of *asexual* — that is, not sexual — reproduction, and we shall not appreciate its importance unless we glance for a moment at far higher levels of evolution, and observe the facts of reproduction in certain species, as, for instance, many insects, where sex is a well-established and important fact. These creatures, of course, illustrate sexual reproduction, but it is well known that, notwithstanding the fact that at some time in the life-cycle of these forms both sexes are present and participate in reproduction, at other times the females alone can and do give rise to new individuals. This phenomenon is known as "parthenogenesis," or virgin-birth, and a notable case of it is furnished by the social bees.

When both sexes of these insects are concerned in reproduction, the offspring develop into females, and, according to the food they receive, become either queens, which are perfect females, or workers, which are stunted and imperfectly-developed females. But where the females alone are concerned — that is to say, when the eggs of the queen have not been fertilized by fusion with the sperms of the male — we find that these unfertilized eggs develop into males, or drones. This type of reproduction is frequently referred to as asexual simply because only one sex is concerned and there is no fusion of gametes; but this is not at all comparable with the modes of asexual reproduction previously discussed, in which every member of the species has the power of reproduction. Furthermore, the cell that develops into the male or drone of the social bees is derived from the same tissue — the germinal epithelium or germ-plasm — as is the egg that is fertilized to produce a worker or a queen, and many authorities maintain that in the maturation of an egg capable of developing parthenogenetically there is no reduction in the number of chromosomes within the cell, a phenomenon that is constant in the maturation of the sex cells or gametes that are to fuse to produce a fertilized egg.

We cannot, however, discuss sex or sexual reproduction without first studying the case of cell-division in the growth of tissue in the higher forms. This is necessary because we shall find that the nuclei of what are called germ-cells play the essential part in the process of sexual reproduction, and we shall be in some degree prepared for the remarkable behavior of the nuclei in these cases if we find, first, how a nucleus behaves in a dividing cell, apart from sex at all.

What we can see in a dividing cell under the microscope

Let us, then, see what happens to and in a dividing cell in the body or somatic tissue of an animal. When it is full grown it divides. If we observe it under a high-power microscope, we find that the process depends upon the nucleus, and that the division of the cell as a whole is simply the last step, after a series of other steps have been taken by the nucleus. Not until they are completed, and have resulted in two complete nuclei, lying inside the cell, one rather towards one side and the other rather towards the other side, does the cell as a whole divide. The general cell-plasm, or cytoplasm, plays an entirely subordinate part.

It initiates nothing, and it does nothing until the very end, when it simply parts in two, so as to inclose each of the two young nuclei with a cell-plasm of its own. We must regard the cytoplasm as a subordinate part of any cell which has a nucleus at all. It protects the nucleus, contains, and even obtains, nourishment for it, and doubtless receives and eliminates the waste products arising from its activity; but cell-division and reproduction in all cells, animal or vegetable, that have nuclei, are dependent upon nuclear division.

The marvelous system which must have its home in the nucleus

Among the lower forms of life, such as amœba, nuclear division consists simply of an elongation of the nucleus followed by a constriction and splitting of the nucleus into two equal parts which is then followed by a division of the cell as a whole. But among the higher plants and animals we find that the nuclear division depends upon a long series of changes inside the substance of the nucleus. Their object, it would appear, is to insure, as far as possible, that every tiniest part of the nucleus, which must have many parts, each with its own uses and functions, shall be scrupulously divided, so that each of the daughter nuclei and each new cell shall have a due share of every part of the parent.

We know that, with important qualifications, species indefinitely maintain the specific characters of their type. This could be only if, in the course of the cell-divisions upon which the history and existence of each species depends, there was this just and exact subdivision of the nucleus in minute detail, so that a little portion of everything went into every member of the next generation.

We know that a cell-nucleus, wherever we find it, has a definite structure. It may be the nucleus of a human gland-cell, or the nucleus of a cell which will develop into a human being, or the nucleus of a cell of an oak. In every case it has essentially the same structure, having a complicated network which stains well when dyes are applied to the cell, and is therefore called the "chromatin."

The mysterious breaking-up that occurs inside the nucleus

If, now, we carefully watch the nucleus when it reaches the period which demands cell-division, we find that the nuclear network begins deliberately to break up and resolves itself into a number of lengths or pieces, each quite separate from the rest. The number of these pieces, in any species, is constant, and is maintained in every cell of any part of any individual of the species. If we should examine the cells in the tissues of a mouse, we should find that the number of the chromosomes in any dividing cell of any mouse, and in the cell from which any mouse is made, is always the same. Sixteen is a very common number, but in some species it is eight, in some twelve, and so on; but while the number, whatever it be, is usually even it has been found that in some animals the number is odd in one sex and even in the other of the same species. This is not a matter of chance, nor a trifling curiosity, as we shall learn when we come to study sex and its consequences.

Subsequent stages and the meaning of "karyokinesis" and "mitosis"

The next stage of division involves much movement inside the nucleus, and so do future stages. This entire process has therefore been given the name of "karyokinesis" or "mitosis," which terms stand for all of that series of complicated phenomena involved in this type of nuclear division, and it is in the study of karyokinesis that the ultimate problems of development and heredity are now slowly beginning to find their solution, or the key to their solution.

The pieces into which the chromatin network of the dividing nucleus breaks up are called "chromosomes," or color bodies, and the next fact we observe about them is that, no sooner are they formed, than they proceed to arrange themselves in regular fashion in the very center of the nucleus where each individual chromosome splits lengthwise, thus giving rise to two chromosomes and so doubling the number in the cell.

The amazing processes of breaking down and building up inside a living cell

At this stage of the game at two opposite sides of the nucleus we find a small round object from which proceeds what looks like a number of fine threads, moving toward the center where the splitting chromosomes are arranged in a sort of plate. The figure thus made is like a spindle, as the accompanying series of pictures show. When the chromosomes are split, one-half of each seems to be drawn towards one pole of the spindle, and the remaining half to the other. At the end of this stage, if the dividing nucleus had sixteen chromosomes we therefore have sixteen halves of the original chromosomes at one side of what was the nucleus, and sixteen at the other. Little more is required for each set of sixteen to settle down at its own pole, for the separate sixteen, in each case, to fuse together, and form a nuclear network once more, and now, in a little while we have two nuclei in the cell, the cell-body divides between them, and the process of cell reproduction is completed.

The exact reproduction of the cell in two perfect halves

We must particularly observe that this whole process has been orderly and precise, and that its object has clearly been to obtain a just and complete subdivision of the structure of the original nucleus, so that its daughter nuclei may each have half of everything that was in their parent. And we observe how the splitting of the chromosomes and the careful withdrawal of the split halves, each to its own side, insures that, in each of the daughter nuclei, the number of chromosomes shall be the same as in the parent. Thus, from generation to generation, the particular number characteristic of the species is maintained. The sixteen in each daughter nucleus fuse and form a network. But when the new cell divides, in its turn, its nuclear network will break up into sixteen chromosomes, as its parents did; and each of these sixteen will split — and so the process will be indefinitely repeated.

It is plain, however, that a difficulty must arise in connection with sexual reproduction where the new generation is formed by the cell-union of a cell from an individual of one sex, and a cell from an individual of the other. Each of these cells will, of course, contain a nucleus, the chromatin of which consists of, say, sixteen chromosomes. If, now, these two nuclei fuse, will not the number of chromosomes in the new nucleus, and, therefore, in the new generation, and in every cell of the new individual, be not sixteen but thirty-two? It would naturally seem to be so.

Whatever the number of stages in karyokinesis there is no question of the fact

We shall later see how, along with the evolution of sex, a remarkable arrangement has been developed whereby this apparently inevitable doubling of the number of chromosomes in successive generations is avoided.

The process of karyokinesis has been studied with minute care in a vast number of species, and different observers vary in their description of the minuter details. Certainly, also, such details vary in different species. Great discussion is maintained on this topic, but it is of little importance whether one observer describes ten stages in karyokinesis and another twelve. There is no question as to the essential fact, which is the formation, and splitting, and due allotment of the chromosomes.

There is, however, one other fact which must be mentioned in connection with this important process.

In a typical animal cell, but not in the cells of the higher plants, close to the nucleus, but not in it, we find a small object, quite distinct, forming part neither of the nucleus nor of the cytoplasm, which is called the "centrosome." We shall not make headway with this subject until the unfortunate clash between centrosome and chromosome has been overcome by the memory. The centrosome, though it is not part of the nucleus, plays an essential part in the process of cell-division, and itself scrupulously divides into two parts.

The center body of the cell which initiates the wonderful changes

Also, it is the centrosome that starts the process of karyokinesis of the cell. If we watch the cell, we find that, before the nucleus begins to show changes, the centrosome does so, and it is clear that the centrosome stimulates and initiates the nuclear changes in those cells wherein it is present.

This wonderful instrument of life, which is clearly shown in the pictures appearing on other pages of this chapter, is thus most clearly entitled to its name as the central body of the cell. The centrosome divides, its halves part, and these two halves are the two directing and essential bodies from which proceed the cytoplasmic threads that control the splitting chromosomes, and draw the split portions to their appointed places.

The problem of karyokinesis which lies at the heart of life

Karyokinesis, or nuclear division, lies at the very heart of the problems of life. Whether it be a somatic cell dividing into two, or a germ-cell uniting with another germ-cell to form a new single cell, which in its turn divides to form the billions of cells in the body of a new individual, karyokinesis is the essential and central fact of all these processes. If it is remarkable in a somatic cell, as in the cells of growing skin, or the dividing and multiplying cells of the skin at the edge of a healing wound, it is much more remarkable when studied in the light of sexual reproduction, with its new complications and consequences, as we shall see.

But even altogether quite apart from its meaning and purpose, the mere series of facts is amazing. The detail is so precise and complicated, the order and program so clearly laid down, the result so exact, and the whole process so unfailing — yet all conducted in an arena where only the highest powers of the microscope can discern anything — that it beggars all attempts to explain, and we are tempted simply to give up the task as hopeless.

This, however, we must not do.

The attempts to reconstruct the invisible factories of life

Experimenters have long endeavored to construct artificial cells, with artificial nuclei, on a large scale, from all manner of suitable materials, and to persuade these artificial nuclei to behave as real nuclei behave, under the influence of electrical forces, or magnetism, or exposure to light and so on. Enough success has attended these attempts at artificial karyokinesis to show that life uses the various forces of nature for its purpose — though, verily, we knew that already. They do certainly suggest that electrical, magnetic, chemical, and other physical forces and laws are at work in the cell, and that they are even employed in the purposeful series of changes by which the nucleus divides and initiates the process of life development.

But we are grossly deceived if we suppose that these experiments explain away the unparalleled character of the facts. On the contrary, the more we know in the realm of cell life, and the more we succeed in applying the laws of not-living matter and energy to the processes of the cell, the more clearly we see that there are still further steps to the heart of the matter.

The laws which are not the creator but the instrument of life

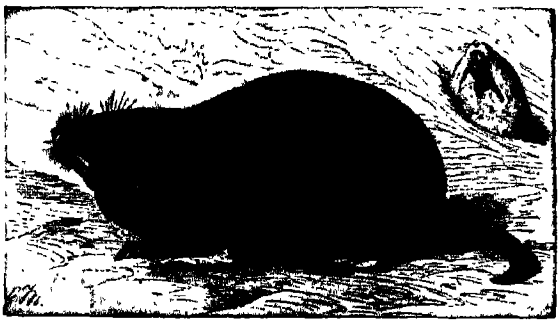
Science may fully claim to have proved that life obeys and is subject to the laws and forces of the universe in general. That in itself is a tremendous generalization, and we can never have too much detail in support of it. But the view of fifty years ago, which argued from this great conclusion to the further conclusion that life is no more than a particular illustration and consequence of mechanical laws, is no longer maintained by those who are the pioneers in this field. They will be the last to return to the obsolete and puerile view that life is lawless, capricious, arbitrary, and only connected by accident with the not-living world; but they will also be the first to proclaim that, while life obeys the laws of physics and chemistry, these are not life's creator, but its instrument.

THE EARTH'S INVISIBLE ARMY

The Story of the Busy Workers who Toil Unseen that we May Live

LIFE IN NATURE'S KINGDOM OF THE SOIL

THE discovery that the soil contains an immense number of living organisms has cleared away many obstacles which have heretofore blocked a true understanding of the soil. Previously the soil was considered only under two aspects: chemical and physical. When its composition and its mechanical condition were seen to, everything possible for bettering crop development was apparently done Even after such precautions were taken numberless problems both scientific and practical remained yet unsolved, and they have been solved only by taking into account the life in the soil, especially the bacteria Of all the phases of soil study the biological is certainly the most fascinating, and scientific workers have united in a hot hunt after the new mysteries. Discovery after discovery has been reported until we can tell the history of life in the soil in a fairly connected way These discoveries have added much to the certainty, the stability, and the permanence of agricultural practice.



THE COMMON POCKET-GOPHER

These rodents bring to the surface vast quantities of soil which they mix with dead vegetation, thus aiding in the production of a fertile soil

Large organisms of the soil

It might be well before we begin our study of the life of the soil to divide it into two groups: the large organisms and the small organisms.

This is the most convenient way for our discussion. From the standpoint of soil fertility the smaller forms of soil life are the more important. The large organisms are represented by rodents, insects, worms, and roots. The last is a plant form, the three others belong to the animal kingdom.

Squirrels, mice, moles, gophers, groundhogs, and prairie-dogs are the more important rodents that inhabit the soil. They are now rather unfavorable to agriculture and the farmer is interested in their elimination. Their activities have been, however, of some importance in that the mixing due to their digging, the letting in of air and the promotion of drainage have aided considerably in increasing the fertility of the soil. We appreciate their work but we do not feel that their presence is longer necessary for the best interests of mankind.

Insects probably perform a similar action but to a less degree than rodents. Numberless beetles, bees, and flies pass part of their life in the soil, and may have considerable effect on the movement of soil particles. Ants, above all insects, are the most important. Have you ever watched a busy colony of ants and noted the minute particles of earth which the workers are bringing out one by one? Extremely slow and laborious digging, I

hear you say! Quite true, but remember that this has gone on for thousands, yes millions of years. Will not the aggregate mixing, fining, and granulating amount to something? Think of the tons of earth the ants have moved! Think of the organic matter that has been mixed with the soil through their efforts! Do you dare now to say that insects are not to receive some credit as soil builders?

furrow slice would receive such treatment every one hundred and fifty years. One hundred and fifty years! Two lifetimes! Yes, but what is this to nature? A mere moment in the creation of a soil! Nature counts in millions not in hundreds. On such a basis how potent the action of the earthworm must be, and how much we must owe to his plowing and industrious delving!

THE FIRST PLOWMEN OF THE EARTH
Earthworms not only aërate the soil but they also bring many tons to the surface, thereby renewing the upper layers.

The earthworm as an inhabitant of the soil is the most important animal. The mole, the gopher, the beetle, and the ant have done their service. We are grateful, but they must go. They are harmful to present-day agriculture. The earthworm, like them, has been useful but, unlike them, he may still remain a benefit to mankind. His actions continue to enrich the soil without interfering with crop production.

It has been estimated that as much as ten tons of earth may pass annually through the bodies of the worms in an acre of soil. This would mean that the whole

Even to the farmer of today the earthworm is of value. He bores holes which aid drainage and facilitate air movement. He brings soil to the surface even faster than the ant. Instances have been known where the fertility of the land was seriously impaired by the killing of all the worms. Crops grown on soils well stocked with worms are found to be larger than those on soil not so inhabited. So convinced is the Chinese gardener of the benefit of the earthworm that he takes especial pains to save him from harm when spading his soil.

Plant roots contribute to the earth's productiveness in several ways. They penetrate the upper and lower depths of soil and on their death leave vast quantities of organic matter to decay in intimate contact with the soil grains. Moreover, this decay opens the channels bored in the soil by the growing roots. These channels serve as air passages and especially as routes of water movement. We little realize how much tile drainage is aided by such seemingly small factors.

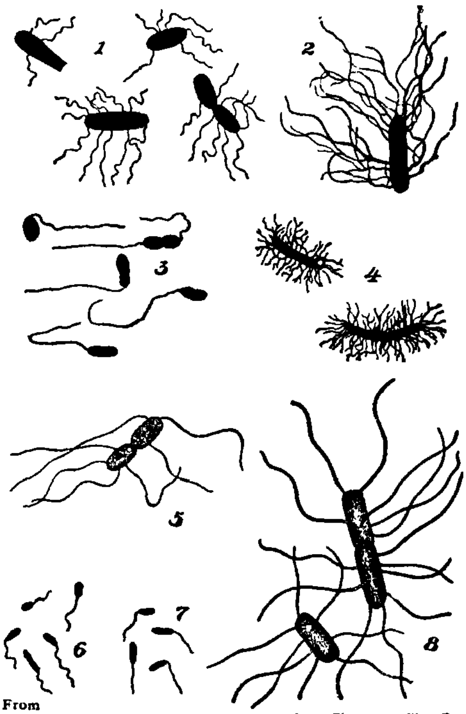
The small organisms of the soil, harmful and beneficial

We have seen that the greater proportion of the large organisms of the soil belong to the animal kingdom. With the minute forms of life the reverse is true. Among these forms plant life reigns supreme. These plant forms may be grouped under four heads — molds, fungi, algæ, and bacteria. The last and by far the most important of these, and of all soil life in fact, are the bacteria or germs.

As we are studying the soil from the standpoint of the plant it might be well to consider small organisms from this point also. With this in mind these minute forms of life naturally fall under two heads: those injurious to plants and those that are beneficial.

The microörganisms that are detrimental to plants are largely parasitic in their habits. They usually attack the plant through its roots. These diseases stay in the soil a long time even if the plant that they like to infest is not grown. As a soil once infested will stay so for a number of years, steps must often be taken to rid it of its disease. This can be done in the greenhouse by heating the soil with steam. With some growers this is a common yearly practice whether their soil is infected or not. They want to be sure that every precaution is taken to prevent disease among their plants. The common diseases that are due to microörganisms are galls, root-rot, wilts of such crops as flax, watermelon, and tomato, and the damping off of a very great number of plants. The latter is a common greenhouse disease much feared by gardeners.

Infection is easily carried from one soil or greenhouse to another and great care must be taken with rubbish when any disease is present. It may also be carried on implements such as shovels, rakes, or hoes. A quarantine as strict as though smallpox or scarlet fever were in the neighborhood should be maintained. While disease may be entirely wiped out of a greenhouse or hot-bed, such control is



From Lipman's *Bacteria in Relation to Country Life*, The Macmillan Co.

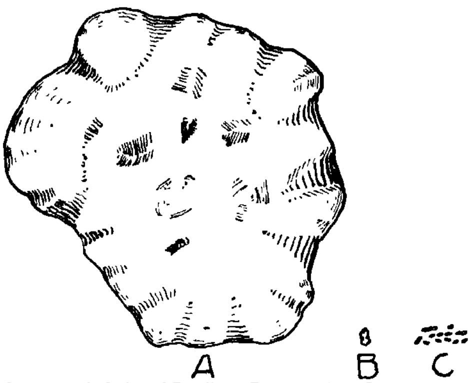
FORMS OF BACTERIA

The bacteria of the soil are generally rod shaped and often possess arms by means of which they can swim from place to place in the soil moisture. The above drawing illustrates the many different forms that are present in the soil.

not possible out in the field. Preventive measures must there be adopted. Care in bringing in seed, use of manure that is free of disease, and the introduction of immune plants are common precautions. Plant breeders are now doing a great work in producing resistant strains just as stock breeders have succeeded in producing animals able to withstand certain conditions. The rotation of crops, that is the growing of a number of different crops in a regular succession, is also practised.

This discourages the disease organism as its host does not appear on the land every year. The addition of lime also is often a benefit as it sweetens up the soil. Clubroot of cabbage is almost entirely prevented by plenty of lime.

In speaking of the organisms harmful to plants we must not forget that they make up only a small proportion of our soil population or flora. Most of the microörganisms are beneficial and as long as everything is going smoothly we forget all about them and how much we owe to their faithful activity. They take almost wholly upon themselves the removal of the dead plant and animal tissues from the surface of the earth, making



From Lyon's *Soils and Fertilizers*, The Macmillan Co.
Bacteria are so small that their presence is often unsuspected. The above diagram shows the relative size of bacteria and some soil particles *A*, a fine sand particle; *B*, a particle of clay, and *C*, a few soil bacteria. All are magnified to the same degree.

them a valuable part of the soil. They thus act as scavengers. They guard the sanitary condition of the soil and keep it wholesome for plant growth. Very often certain plant diseases are caused by bad sanitation just as certain human ills arise from the same cause.

The beneficial microörganisms do many other things. They take nitrogen from the air and make it a part of the soil. They aid in the production of carbon dioxide, the gas which acts as a helper to oxygen in chemical action and to water when in solution. They aid in tearing down the complex compounds both mineral and organic, and lend a hand in preparing food materials for plants, especially those valuable in agriculture.

In all processes of simplification the microörganisms are necessary. In fact, without these forms, animal and plant life could survive but a short time. Plants and animals build up; microörganisms tear down. Were the latter process prevented, where would you and I get our food? No plants could grow, domestic animals would starve, and man would miserably perish!

Bacteria and how they divide their labor

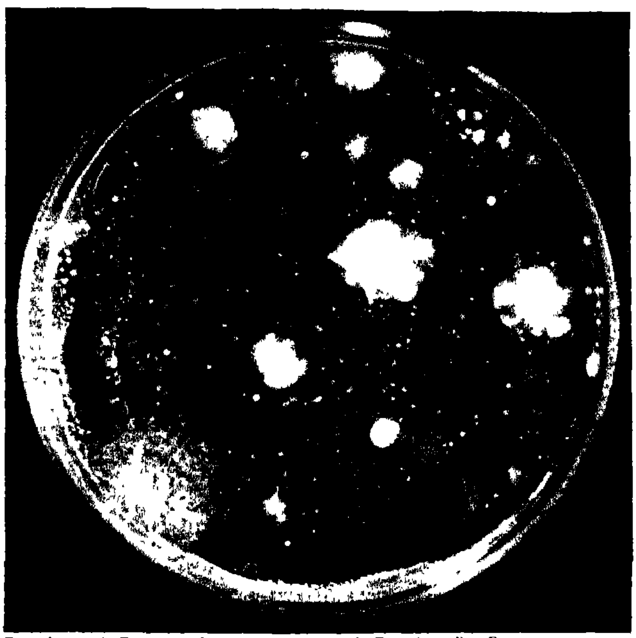
Of all the hosts of life forms in the soil, bacteria are most numerous and most important. These organisms are the lowest and most humble of all plants, being simple little cells, usually rod shaped, filled with active life-giving material called "protoplasm." They are very, very small, a length of one thirty-thousandth of an inch being a common size, although many are much shorter. Many hundreds may be placed on the point of the finest needle. Is it little wonder that so many, many billions may live and function normally in a pound of soil?

As bacteria are plants, we might expect that they would require the same conditions for growth as demanded by higher plants. This expectation is true. They do require the same factors for growth as ordinary plant life with one exception. This is light. They need the mechanical presence of the soil, they need air, heat, water, and food, but light they avoid. As a matter of fact, too much light, especially sunshine, will kill them. They therefore live in the dark places and do their best work in the recesses of the soil. We do not find them responding to the sunshine as ordinary plants do, and this is really fortunate. They penetrate the soil layer and are able to do work where ordinary forms find it impossible to survive. They live mostly in the soil moisture, swimming about as chance may direct, or clustering in layers at various advantageous places. Their food comes from the soil and air very much as with ordinary plants.

The conditions of optimum bacterial action, leaving out light, are exactly the same as for the higher plants. This is a fortunate thing for the farmer.

If he regulates the soil as to air, heat, moisture, and food to best suit the needs of his crop, he does so equally for the bacterial hosts beneath his plow. He does not have to worry about his minute tenants, as they respond to the regulations beneficial to ordinary plants. The means of stimulating bacterial action are common ones. Deep and thorough plowing, drainage, conservation of moisture that an optimum amount may always be present, and the maintenance of plenty of organic matter are well known. Lime is sometimes beneficial as it sweetens the soil and removes some of the products that may be harmful to the bacteria. We must remember that ordinary everyday practices are the means of stimulating and encouraging the teeming millions of this kingdom beneath our feet

With such a great number of different things to be done and such a great bacterial population, we should not be surprised to learn that some sort of a division of labor exists. We would hardly expect to find a single organism attacking a fragment of dead plant tissue, for instance, with the purpose of resolving it through many complex stages to the simplified condition that it must attain before being used as food for plants. No particular individual is equipped to perform labor comprising so many difficult and complicated operations. Nor is it necessary. Millions of individuals exist in every fragment of soil. The work may be divided up, each individual or group of individuals performing one or two operations and then passing the product to the next and so on. It is a system much like our modern factory where piece work is the common practice. Such a division of labor makes for efficiency in every sense. The work goes on faster and the quality of the product is better. Perhaps the wonders of the transformations that take place in the soil are partially due to this system.



From Lipman's *Bacteria in Relation to Country Life*, The Macmillan Co.

BACTERIA GROWING ON AGAR

Soil bacteria may be grown on artificial medium Wherever the agar originally contains one organism a clump or colony develops This clump may become so large as to be seen with the naked eye. Note the differences as to size, shape and character apparent between the various colonies

As such an organization exists among the bacteria let us inquire first into the divisions and then into the departments or subdivisions of each. The divisions are based as might be expected upon the materials to be worked on. This is natural. It is just what we would expect in any factory or workshop. But what are the materials to be broken down and simplified? Mineral and organic material, you say. The latter is susceptible to further division and into what? Carbon compounds and nitrogen compounds is the answer to that question. This gives us then three groups of bacterial workmen: those that deal with mineral matter, those that transform carbon, and those that have to do with the very intricate changes of the nitrogen. These workers do not have separate factories or separate rooms in the same factory. They

labor side by side in what seems to be at first a terribly mixed and haphazard fashion, but which in the light of present-day science is perfectly reasonable and efficient. They are all experts and in a normal soil the work goes on with a smoothness and a rapidity that excites wonder and admiration.

Mineral bacteria

The particles of the soil have been shown to expose an immense amount of internal surface, and upon this surface the bacteria are able to exert a tremendous effect. As they float about in the water which bathes the soil grains or lie in great mats against some of the larger particles, entrapping at the same time innumerable small fragments, they are in an advantageous position to carry on their work. Their influence is exerted in two ways: directly and indirectly. In the former the bacteria themselves attack the soil minerals. In the latter method of operation materials are produced by the organism which in turn are able to simplify the rock fragments.

Just exactly what the nature of the direct action of the bacteria upon the rock fragments is, it is impossible to say. Perhaps the mineral materials are taken up by the organisms, part being excreted again in a condition valuable to plants. The other portion perhaps becomes a part of the bacterial cell to be liberated later when the organism dies. Several different groups of mineral organisms have been found and are named according to the elements upon which they work, such as phosphorus, iron, and sulphur. Just what proportion of the soluble mineral elements in the soil solution can be attributed to the direct activities of bacteria, it is difficult to state. We only know that their influence is important.

All bacteria produce carbon dioxide in large quantities. This gas becomes dissolved in the soil water, making it slightly acid. This acid condition increases the solvent power of the water and influences to a marked degree the amount of mineral matter which becomes available to plants. Bacteria also produce organic acids which exert the same action as does the carbon dioxide.

Of the two general modes of attacking and unlocking the difficultly available food, the indirect method is perhaps the most important. It is no doubt the less efficient, but as such immense quantities of carbon dioxide are being continually liberated the aggregate influence upon the solubility of the soil minerals is greater.

Carbon bacteria

Carbon is one of the elements always associated with life. It seems to be necessary for animate form. It exists in the air as carbon dioxide and in the soil as organic matter. It is used by plants in various ways, and this use is clearly related to the activities of soil bacteria. It comes from the air and to the air it ultimately returns. Let us trace the course of this carbon from one gaseous state to another and see the intricate path that it must follow, as it serves the needs of plant and animal life.

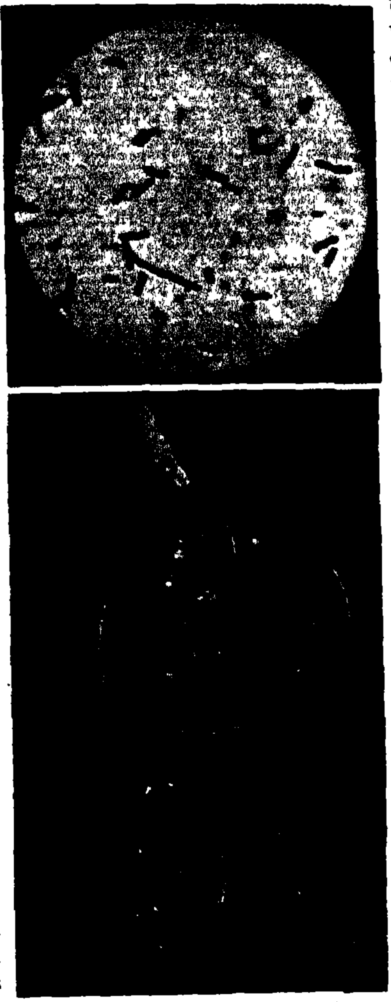
As already shown, plants have the power of taking carbon dioxide from the air by means of their leaves. The gas enters through openings called "stomata." Once inside, the plant, by virtue of its green coloring matter and sunlight, tears the gas apart and appropriates the carbon and part of the oxygen. The carbon is then used in making such compounds as starch and sugar, which we find so largely in plant tissue.

A large part of the potato and of other vegetables is made up of carbon and other elements such as oxygen and hydrogen drawn from the air. The soil has little to do directly in furnishing such materials.

The carbon from the air existing now as a part of the plant has been built up into complex compounds. When the plant dies this carbon goes into the soil. It is so complex that succeeding plants cannot use it. It needs simplification. This is where the soil bacteria must be called upon. They take this tissue, tear it apart, and very quickly resolve it to water and carbon dioxide. In other words, they simplify it until the carbon emerges in the same form as it was when taken up by the plant.

The gas may now go in either one of two directions. It may escape into the air, thus completing the circle or cycle, and be again utilized by plants. Or it may remain in the soil and aid the oxygen and the water in bringing about important chemical changes. The fact that soil air may contain two hundred times more carbon dioxide than atmospheric air seems to indicate that often this path is followed. In time, however, even this carbon gets back to the atmospheric air in its original form

Suppose now that for some reason the bacteria were unable to effect this transformation. The carbon would soon be all tied up in complicated forms and unavailable for plant use. Crops would soon be starving in the midst of plenty, and we in turn would perish with the plants! How closely the fortunes of all life on this earth are tied together and how wise are nature's plans for co-operation and mutual support!



NITROGEN FACTORIES AND WORKERS

It has long been known that the nodules on the roots of certain plants, such as clover and alfalfa, increase the soil nitrogen. It is now known that each nodule is full of bacteria — magnified a thousand times in the above picture — capable of appropriating the inert nitrogen of the air and making it useful to plants

Nitrogen bacteria

Like carbon, nitrogen is very closely identified with all life processes, and consequently its changes and transformations are of vital importance. It exists in the air in an elementary form and in vast quantities. All of the nitrogen in plants and in the soil has originally been drawn from this source. The means employed in obtaining such nitrogen and the combinations and changes of combinations that it afterwards undergoes, make a wonderful story. Nor have scientists yet unraveled all of the mystery. Much remains to be worked out. The study of soil nitrogen is a most fascinating as well as a most productive field for research today. Its secrets have a vital importance to our everyday life, and what we have already discovered has advanced to a great degree the science of agricultural production. Let us trace as best we can the paths the nitrogen must travel in its usefulness to man.

Nitrogen fixation

Our first inquiry is, how can this gas nitrogen be taken from the air and become a part of the plant or the soil? What are the forces that function in this apparently impossible feat? Nitrogen is a very inert gas. It does not react readily with anything at ordinary temperatures and even when combined with other elements it escapes the union if possible. Is there some magic in the process? No. The plan is simple enough when we once understand it. It is similar to the way that carbon is taken from the air by the green leaves of our ordinary field crops. In the case of the nitrogen, however, the work is done by certain forms of bacteria which live in the soil, and with energy obtained therefrom are able to appropriate the free nitrogen from the air. The action is no more wonderful than many others that we see every day and have become accustomed to. It is because it is strange and invisible that we imagine it to be a wholly new and original invention of nature.

This nitrogen is appropriated by two distinct groups of bacteria. One set lives in the soil just as do ordinary bacteria. They use as food the organic matter already in the soil, and from the energy derived therefrom they are able to appropriate the nitrogen from the air. This nitrogen is combined with other elements by the bacteria and either excreted into the soil solution or laid up in their bodies. The nitrogen in either case becomes a part of the soil. The bacteria, because they live free in the soil, are called "free fixers." They are rather important although the amount of nitrogen fixed is not large, probably amounting to only a few pounds per year to the acre.

The other group of bacteria that fix nitrogen leads an entirely different existence. They are parasites, but unlike most parasites they are a help and not a mere encumbrance. They live in the roots of certain kinds of plants called legumes, of which clover, alfalfa, peas, beans, and vetch are common representatives. Early in the life of the plant the organism gains entrance into certain of the rootlets. The plant juice furnishes a plentiful and healthful source of food. The bacteria multiply and the plant, to segregate and control them, forms nodules or galls. In these galls the organisms live, and by means of the energy derived from the host plant they are able to appropriate and fix the nitrogen of the air. They are generally called the "nodule" or "legume organism" to distinguish them from the free-fixing bacteria just described.

From Whitson and Walster's *Soils and Soil Fertility*, Webb Publishing Co

LUPINE WITH AND WITHOUT INOCULATION

Plants carrying the nodules on their roots are better supplied with available nitrogen than plants not so infected. Note the difference in size of the two groups

The nitrogen fixed by these organisms may go in several directions. It may be used directly by the plant, giving that healthy green color possessed by legumes that are inoculated or infected by the bacteria. It may become a part of the soil solution and stimulate plants growing with the legume. The growing together of clover and timothy is a recognition of the practical value of such an association. Some of the nitrogen, however, becomes a part of the bacteria, being laid up as complex nitrogenous compounds in the cell. When the crop is cut and the roots and nodules decay many of the organisms die, and this nitrogen becomes a part of the organic matter of the soil. It must be simplified, however, before it can be used.

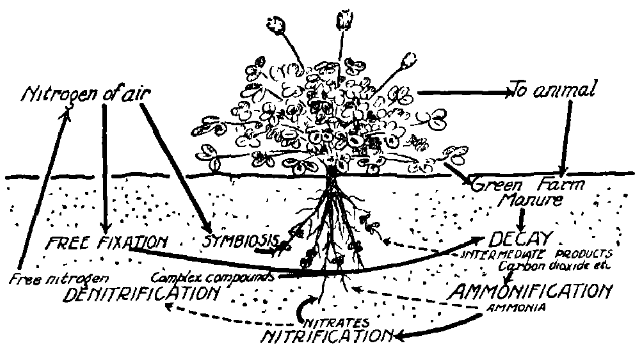
The fixation of nitrogen by the nodule organisms is generally considered as more important than the work of the free fixers, as the amount taken from the air in a year is much greater. As high as forty or fifty pounds per acre may be added to the soil in a year by this process. This is equivalent to the addition of two hundred and fifty pounds of a nitrogen fertilizer. For that reason the farmer should always have soil conditions such as to encourage the presence of the bacteria. A well-drained granular soil with plenty of humus is the first necessity. If the soil is the least bit sour, it should be limed to sweeten it. The response of the organism to lime is well known.

Two complicating features enter into the practical control of this process of nitrogen fixation.

The first of these is that different strains of organisms are found on the different legumes and they are not generally interchangeable; that is, the organism of the alfalfa will not grow on the clover and vice versa. Second, the soil may not contain the particular bacteria required. These two conditions often necessitate the inoculation or introduction of the required legume organism into the soil. Soil from fields known to be well stocked with nodules is sometimes used. Sometimes the seed is inoculated before planting. At the present time, methods have been so perfected that failure seldom occurs. The farmer, in fact, becomes his own bacteriologist.

Nitrogen transformations

We now understand how nitrogen from the air is utilized by plants and introduced into the soil. This does not dispose of the subject by any means. What of the nitrogen which is locked up in the organic matter as complicated compounds? We know that it is not available in this form. Does it ever become of use to the plant? Our knowledge of the way in which carbon compounds are simplified tells us that probably the nitrogen compounds undergo the same general process. This guess is true. First a group of bacteria attack the nitrogen compound and take it through the process known as "decay." This product is not much simpler than the original. In fact, it may be much more complex. It now passes to other workers, who reduce it to what is called "ammonia." Ammonia is a compound of nitrogen and hydrogen and is very simple compared with the original combinations.



From Lyon's *Soils and Fertilizers*, The Macmillan Co.

THE NITROGEN CYCLE

This diagram shows the two groups of nitrogen-fixing bacteria indicating as well the processes of decay, ammonification and nitrification Most plants absorb nitrogen in the nitrate form

The nitrogen of this ammonia is not yet ready for the consumption of most crops. It must undergo further change, and a very important change at that. Most bacteria can do a number of things but the group that take this ammonia in charge are strict specialists. They do but the one thing only. They add oxygen to the ammonia and change it to a compound of nitrogen, oxygen, and some mineral element like calcium or potassium. This compound is called a nitrate, and it is from this form that most plants take up the greater part of their nitrogen.

Importance of nitrogen bacteria

The changes that nitrogen undergoes are many and they are complicated. Moreover, they are important. If the chain of actions which are continually producing nitrates is broken, the plant must suffer. Its food is cut off. It behooves the farmer to encourage and stimulate his bacterial tenants to the greatest degree. This cycle from air to plant, from plant to soil, and from soil back to plant must go on. Not one link must be missing. The control of the bacteria means the control of fertility. We can now see why the study of our soil life has added so much to both scientific and practical agriculture. The control fortunately is simple. It has already been stated in connection with soil moisture. Keep your soil in the best condition for plant growth, and you have the conditions at the optimum for all favorable bacterial activity. Under such conditions minute organisms of all kinds in the soil seem to function in such a way as to be most useful and helpful to higher plants.

THE WOLF APPROACHES THE CITY, LED BY THE SPECTRE OF FAMINE

In this picture Mr J C Dollman has suggested the advance of the wolf to the gates of the city led by the spectre of famine Famine and the wolf were associated terrors in the days of early man, and so continue in the wilder parts of Europe to this day When winter grips the land and lesser animal life is dormant the grim and famished wolf still turns upon man himself

SAVAGES AT OUR GATES

The Life-Stories of Hyenas, Wolves, Jackals, Dingoes, Foxes and Wild Dogs

WILD LIFE ON CIVILIZATION'S BORDERS

TODAY, upon the border line of civilization, there skulk the same species of animals which challenged man in the long ago. The savages of Africa, and the scarcely civilized natives of remoter India, pass their lives in the midst of these beasts. They are fighting the battle for the preservation of their homes and of their flocks and herds against their animal rivals just as early man fought his battle. The ranchman, pushing into the wilds today, finds that the frontiers of the native fauna do not merely begin where man's end; his and theirs overlap. Not consciously, but by their actions, they resent his intrusion. The game which would have been theirs vanishes at man's coming, and they make his flocks supply the deficiency. In certain parts of the Old World where the involuntary association with animals is of long standing, we are afforded a glimpse of the means by which primitive man first came to domesticate the savages of the wild. There is apparently a tacit understanding between these people and the hyena and the jackals. Even the fierce wolf has surrendered members of its family to their homes.

The relations today are really but little changed from prehistoric times. Wolves, hyenas, and jackals hang upon the outskirts of human habitations, as robbers, as tolerated snappers-up of trifles; here and there one of their number becomes an inmate of the human settlement, and we see how man got the dog. But the untamed majority are relentless pillagers of flocks, and show us how man would first experience the need of a fierce and devoted animal, capable of driving off marauders.

At first sight it might be assumed that the hyena holds some sort of relationship to the dog, the wolf, and the jackal, but it is another triumph for the comparative anatomist to have traced the descent of this animal. The hyena's nearest relative is the aard-wolf. Together they trace back, not to the dog tribe, but to the civet family. Of course, the families are quite distinct today but in the story of their past, so closely do the forms approximate, it is impossible to say where civet ends and hyena begins.

The hyena has gone through life by proving that he who fights and runs away lives to fight another day. Three distinct species flourish — the striped, the brown, and the spotted. The first is common to Asia and Africa, with domiciliary habits varying with its habitat. It may occasionally frequent forests, but it is more commonly found in sandy and rocky plains. It is the ghoul of the rock-cut tombs of Palestine and Syria; in India it is to be found lurking in cities once teeming with human life, or, still more frequently, in caves and rocks. The brown hyena is a South African species, fewest in number and more restricted in range. The spotted species, the unloved king of the family, ranges widely over Africa. It was once in India; it abounded in most parts of Europe. It must have been a rare moment in the life of the naturalist who was first able to prove that the bones of the hyenas belonging to a distant epoch were those of animals specifically identical with the spotted hyenas of today — a little larger, perhaps, but not different in any other way.

The cowardly hyena will flee from a healthy man but attacks a sick one

By this fighting and running away have the hyenas, now divided into three species, maintained a good place in the battle of life. The spotted hyena, the most powerful of the family, is one of the most hated of animals. It is such a coward, yet so cruel. Associated in loud-howling packs, it will on occasion show considerable skill in the capture of its prey, but it is the sneak-thief of wild life. Sheep and goats it will take, of course, but there is something revolting in the way in which, fleeing like a phantom from a healthy man, it will kill and carry off a sick man, or snap up a tiny child. With its great bodily strength, it unites unequaled power of jaw, enabling it to crack the shin bone of an ox with as little difficulty as a dog can crunch the bone of a fowl.

This power of the hyena is generally referred to its superb teeth, but it is sometimes forgotten that the vertebræ of the neck are furnished with muscles so developed as make the entire neck appear to possess but a single joint. But the animal, fortunately for mankind, does not appear to realize its own strength. It can and does kill many animals, but its nature is to follow in the wake of other carnivores, and to make a meal of the skeleton which they and the vultures have picked clean. A hyena would be a demon of death and destruction on a battlefield where wounded men lay helpless. It will bite the face of a sleeping man — which is, perhaps, rather a bold proceeding for so timorous a beast — but its supreme cunning is shown in its attacks on the natives along the Zambesi River.

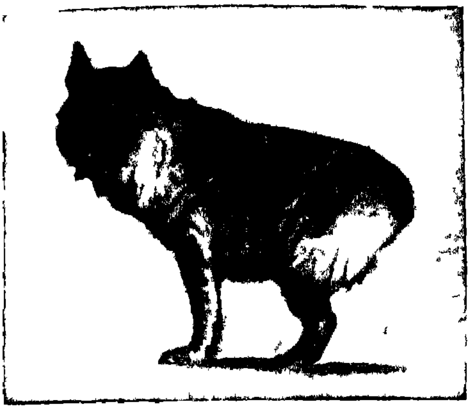
Whether its method is peculiar to the hyenas of that part, or whether the native huts are specially favorable to the plan, we do not know, but there the hyena is dreaded for the assaults it makes upon the natives in the early morning. Not in the open does this happen; the wily beast knows that to leave his hut a man must kneel and crawl out, almost on his hands and knees. So the hyena waits, and as a head pops out from a low doorway it makes its grab.

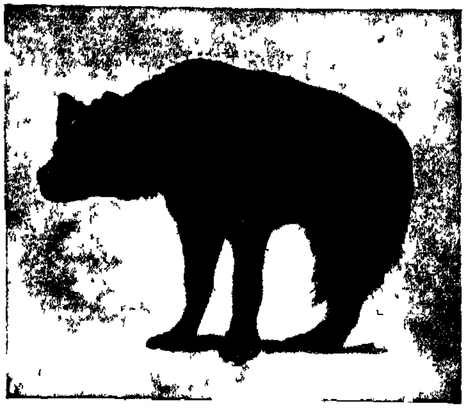
The terrible scavengers that prowl about the towns of Abyssinia

Yet, with all its detestable qualities, the hyena has its pact with man. In Abyssinia, where the animals are abnormally plentiful, they are the chief scavengers; and though it ravages flocks right and left, and is cordially hated, the natives regard the hyena as a necessary evil, and actually cut holes in the walls of their towns so that, when all is quiet at night, the unclean beast may steal in and eat the filthy garbage which the housewife throws into the street. That sort of agreement between man and these animals has probably been in force a hundred thousand years. The style of human dwelling has altered — that is all.

The aard-wolf, akin to the hyena, is a curious animal which has caused the naturalist some perplexity. Arising from the same stock, it has branched off to fill a sort of intermediate position between the carnivorous and the insect-eating animals. With singular and degenerate teeth, it makes it meal of carrion and white ants; it burrows, it comes out only at night, and it flees like a hare if disturbed. It is a singular beast, descended from the civets, resembling the hyena in many points, but having more toes than its cousin and showing a head rather like that of the mongoose. It was said to inhabit only South Africa, but its range is now found to be wider.

We owe nothing to the hyena or the aard-wolf save the service they render in savage or semi-civilized lands as scavengers. But in the case of the dog family we have grim enemies in the wolves, and unclean, skulking beasts in the jackals; we have the robber of hen-roosts in the fox, but we have also the dogs proper. With the wolves and the jackals, possibly producing a general type of which the dingo may be a modern representative, man set out to rule the earth, to become a stock-raiser. The dog family is so generalized that it is difficult to trace the line of descent back to any one primitive mammal, but, taking wolf and jackal as we find them, we credit them with the parentage of all dogs.


THE STRIPED HYENA


THE SPOTTED HYENA

With its enormously powerful jaws the hyena should be among the most formidable of animals. It is in a way but a sneak thief and is the assailant of wounded or dying prey. Starting from the same ancestry as the civet, the hyena has developed into the supreme disposer of bone, and present day species crack ox bones as did their ancestors of yore

We must view the wolf, therefore, with some little respect for the boon that he has indirectly conferred upon the human family. A sort of civic life may have begun by his aid. As an old poacher makes the best gamekeeper, so the first wolves that became domesticated were the best animal friends man could have for the preservation of his flocks, his home, and his children from the onslaught of the rest of the wolves. Most animals have what may be called the proprietorial sense. The most timorous bird will boldly assail a larger and more formidable rival which is put into its cage.

A cat will attack another cat trespassing upon its home, or will even assault an animal of a different species for the same reason, for the writer has a vivid recollection of a cat furiously attacking a Shetland pony in whose favor a horse had been ejected from its box-stall. Puss, the friend of the evicted animal, sank her claws with such force into the muzzle of the Shetland as to draw blood. Had some early cat shown the same spirit under like conditions, cats might perhaps by this time have been trained as guardians of human homes, second only in importance to the dog itself.

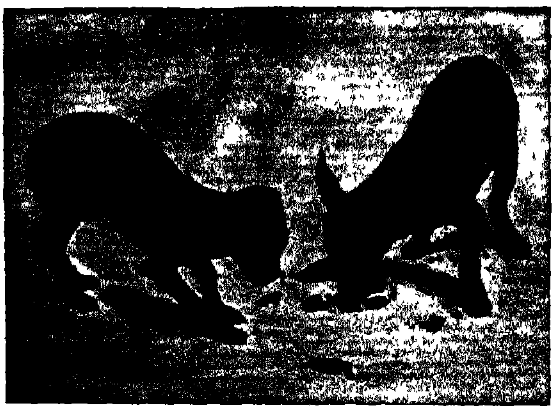

THE EGYPTIAN JACKAL

The largest of this widely distributed group, with a height of 16 inches at the shoulders.


THE BLACK-BACKED JACKAL

This is the handsomest of the group. The beauty of his coat is the more notable when it is remembered how offensive is his normal diet

But the dog has this sense of proprietorship more strongly developed than any other animal. The meanest cur is a little hero in defense of its kennel and of its master's home. The instinct is developed from the wolf's fierce resentment at any interference with its prey, or any intrusion upon its home. A cat will teach its kittens to kill mice, but a dog will fly at its puppies if they challenge its right to kill a rat. And the old-time wolf which man had trained from its infancy in his habitation would fly at other wolves that it might meet on the prowl. The custodian of the home would desert, no doubt, and rejoin its friends of the forest at times, but its cubs would be born at home, and, once there, no competitor from the wild beyond would be tolerated. The association between man and wolves would spring up in course of time upon some such lines as those which govern man's relations with the hyena today. There was ample choice, for wolves abounded in many countries where they are now unknown. Indeed they were not exterminated from Ireland and Scotland until the latter half of the eighteenth century, and in parts of the United States they are still numerous. The Eskimo dogs, and the dogs of the Indians in the southwestern part of the United States, are derived directly from domesticated wolves; and Sir Harry Johnston identifies certain dogs in Achill Island, off the west coast of Ireland, as simply stunted wolves, agreeing with the wolf in color, in brush, in the shape of the ears, and in the arrangement of the masses of hair along the line of the back. The true wolf exists today in France and Germany and Spain, and elsewhere in Europe, and in times of severe weather becomes a terrible scourge in Russia.



A PAIR OF MEXICAN HAIRLESS DOGS

Hairless dogs, the unlovely choice of certain fanciers are found in South and Central America, China, Manila, the Antilles and Bahamas

The wolves of North America are of only three kinds, and perhaps only two, for there is no certainty that the great white (sometimes black) wolf of the Arctic coast and the Barren Grounds north of Hudson Bay, is specifically different from the common gray wolf. The other two are the gray wolf and the smaller coyote.

The American gray wolf, timber wolf, or buffalo-runner, as it is variously called, is substantially the same animal as that of Europe and northern Asia. A well-grown example will measure five feet from muzzle to the end of the tail bone, which is itself about 16 inches long; the height at the shoulders is about 27 inches, its weight about 100 pounds. These are the measurements of a large male, the female is considerably smaller. The normal color seems to be a yellowish white under fur gray, many hairs tipped with black, and with brown markings on the ears and about the face; but the coat is very variable in color, ranging even to blackish in southern specimens. This great gray wolf formerly ranged throughout the whole continent, but civilization has driven it to the northern and western fields, where it still abounds on the plains, in the Rocky Mountains and western Coast Ranges, and throughout the forests of northern Canada. Its habits are like those of its Old World cousins, and it was the especial enemy of the buffalo in the old days, as it now is of the deer, moose, and caribou. In the western United States it finds similar prey on the cattle and horse ranches, and constant war, aided by government bounties, is waged against it. Indeed the government now employs numbers of hunters and trappers who spend their entire time combating these predatory animals.

The coyote is a much smaller wolf, and takes the place of the jackals and other wild dogs of semi-tropical parts of the Old World. Although often spoken of as the "red wolf," it shows the same buffy gray tone and has the same darker varieties as the gray wolf. The real distinction is one of size, for the coyote, or prairie wolf, is much smaller. The length of a large male is rarely more than four feet, 14 inches of this being the tail, which is somewhat longer in proportion than that of the gray wolf. The weight averages about 28 pounds for the male and 24 for the female. Coyotes vary greatly, however, so that some systematists have made a dozen or more species and sub-species in northern and central America. These small wolves are restricted to the open regions of the west and formerly ranged eastward into Indiana; but now belong wholly to the thinly settled plains, where they live in burrows, and feed on mice, gophers, rabbits, and the like, and are a great pest to sheep herders and poultry keepers. It is impracticable to reduce their numbers effectively by guns or traps but large numbers are poisoned. The only real protection for ranchers and farm-yards is wire fencing which they hesitate to jump over or dig under.

A SCAPEGRACE — THE PARIAH DOG

Pariah dogs are backsliders They or their parents were domesticated They have run wild, interbred with true wild dogs, and have become scavengers and thieves

The European and American wolves agree in their habits. They frequent open country and forests; they make their lair in rocky caverns, in the decayed trunk of some fallen tree; they even make burrows in the ground, or enlarge those begun by other animals. The wolf has no friend in the world, for he lives, when near civilization, at the expense of man's flocks, and at the cost of human life. The famished lone wolf will attack a man at night; the pack of wolves in winter is the terror of travelers by road. Their ferocity when pressed by hunger is as unappeasable as their strength and endurance are inexhaustible. Their speed may have been exaggerated. Experience proves that they cannot outpace the greyhound, but they can run down the horse; and of the stories of their pursuit and capture of sledging-parties not the half has been told.

Every year the fight of the wolf for existence must become more precarious, for civilization and wolves are incompatible. It is not unusual for them in winter bodily to invade a village. The reason for their successful struggle against extermination is partly that they can exist on a varied diet, and partly that they are exceedingly prolific. The female wolf brings forth from six to ten cubs at a time; she rears them with rare fidelity. Whether there is any truth in the legend of wolf-reared children is a much-debated point. Rome, the home of more than one delusion, still keeps a live wolf in honor in a den within her walls, to celebrate the rearing of Romulus and Remus by the she-wolf who rescued and suckled them after they had been taken from their mother and thrown into the Tiber by the tyrant Amulius; and seeing the extraordinary cases of foster parentage among animals reported from time to time, there may perhaps be some foundation for such legends. One peculiarity helps the tradition in the case of the wolf. The great cats are all rough-tongued. They wash their cubs by licking them. Such treatment would rasp the flesh from the body of a child. Now, all the members of the dog family are smooth-tongued, so any washing process would be harmless.

Present-day habits of the wolf lead to slight credence of wolf-reared children

The wolf in captivity requires from three to four pounds of flesh per day to keep it in good condition, but when at liberty, consuming energy rapidly in its extended forays, the animal would need considerably more than this, with fasts sandwiched between feasts. A child's only hope of escape from death would be on some occasion when the wolf had fed well, and was carrying home prey to its young. In India the native wolf, rather smaller than the American, and less bold — though apt to act in concert for attack upon man — frequently carries away children. Nowhere is the story of wolf-reared children more prevalent than in India. Native evidence as to animals is, as a rule, very unreliable, but there is just the shadow of possibility that from the multitude of cases reported a genuine instance might be found, although no such case is credibly authenticated.

The jackals may be traced through the wild dog and the Indian wolf to relationship with the true wolves. They are a widely distributed family, common to Asia, Africa, and even part of Europe. The common jackal ranges from Burma and India through southwestern Asia to southeastern Europe, but south of the Sahara its place is taken by certain allied forms, such as the side-striped jackal and the black-backed jackal. The largest of the group is the Egyptian, which has a height of 16 inches at the shoulder, and a total length of rather more than four feet. The Morocco jackal is smaller and lighter built, with a decidedly intelligent head of the true canine type. The handsomest of all, however, is the black-backed or silver-backed. The jackal is practically omnivorous; and its appearance makes one marvel at the power of the organism of the animal to convert unpromising material to such good use. There is no offal too foul for the jackal to relish, yet, in spite of its unspeakable diet, the animal carries a magnificent coat, with every appearance of good health and keen enjoyment of life.

Although there is no relationship between the jackal and the hyena, there is much in common in the habits of the two. The jackal is another of the sneak-thieves of creation, wanton and cowardly, attacking wounded game, and snapping off the fat tail of a sheep, and then running away, to leave the victim suffering. Like one or two other carnivorous animals, it will eat readily of vegetable substances, and plays havoc with sugar plantations, destroying a dozen times as much as it eats.

The way in which the jackal has been of service to man for thousands of years

It is an interesting and singular fact that the jackal appears to flourish from association with man. It does not voluntarily make its home near him, it is true, though it lurks in the cities that he has built and deserted. But it is as a scavenger in the track of the hunter that it most profits. Where the man with the gun has been, the jackal follows, and the hyena comes along for the bones. And for the time being, at all events, jackals become more numerous in areas where big game is hunted and killed. As a scavenger, the jackal has its apologists, on the ground that, where all knowledge of sanitation is absent, even an animal which howls nightly through the streets, devouring refuse, is not to be despised. In that sense the jackal is of service to man, as it has been for thousands of years, and on precisely the same terms. But it levies heavy toll on poultry, lambs, and kids.

The jackal has the weirdest of cries; and a pack of these animals wailing in chorus makes the blood of a man new to their music run cold. "Dead Hindu, — where, where, where?" is the not inapt word version of their cry; and the phrase is possibly true to the meaning, for the jackal is a notorious robber of graves.

The dingo, the so-called aboriginal dog of Australia, comes next in order, between the jackals and true dogs. Smaller than the wolf, with moderately long legs, short, broad muzzle, well-developed ears, and a rather long and bushy tail, the dingo is an interesting puzzle. It is the only big non-marsupial in the island-continent.

A SIGHT ONCE FAMILIAR IN ENGLAND—A PURSUIT BY A PACK OF WOLVES

The Saxon name for January was "wolf month," because people were "wont always in that month to be more in danger to be devoured by wolves, as, through the extremity of cold and snow, these ravenous creatures could not find other beasts sufficient to feed upon." During a recent winter wolves killed 161 people and 108,000 cattle in Russia; and the memory of their depredations in England still lives in such names as Wolverton and Woomer. [This painting is by Mr. R. Morley.

ONE OF THE FAMOUS ST BERNARD DOGS WHICH SAVE THE LIVES OF TRAVELLERS LOST IN THE ALPS

A hundred fanciers would have probably a hundred favorite breeds of dogs, but all unite in common admiration of this noblest descendant of the wolf, the St Bernard dog, which is used to save the lives of snow-bound travelers in the pitiless Alps This photograph shows one of these brave creatures with one of the monks who keep them in the famous alpine hostel of St Bernard

The native dog of Australia, which has every man's hand against him

How could this one animal, so vitally differentiated from the rest, producing its young in the manner common to mammals, have been evolved in Australia? The first answer was that it was a recent importation. That did very well for a time, but now fossil remains of the dingo have been discovered in some of the superficial and cavern deposits of the country, in company with remains of species now extinct. Now, this means that the dingo reached Australia unassisted, in some manner not yet understood, or that it was taken there by man in early times.

Possibly this suggestion of man's company is not so wide of the truth as may appear, for it is reported that dingo remains have been discovered with the remains of man. Meanwhile the lineage of the dingo is involved in some mystery

An edict has gone forth decreeing his extermination. He is a scourge to sheep and poultry, and kills with savage wantonness. So the Australian government has pronounced sentence, and the hands of all men are against him. His blood will not die out, for, like the jackal and the wolf, he breeds freely with the domesticated dog. But he is as true a nomad as they, and to keep a full-blooded dingo permanently about a house is impossible.

The time comes when he hears the wild voices of the night calling him, and away to freedom and the wilderness he goes, to become a poultry-thief.

The curious "wild dog" which sleeps through the winter without food

There are many so-called wild dogs. The naturalist objects to this term, asserting that the wolves and jackals are truly the wild dogs. But there is no other generic name for these other groups, and fashion has given them the name that is generally used. The curious raccoon dog of China and Japan is a great curiosity, with long and pointed muzzle, small, rounded ears, with a body slender and arched, set up on short legs, the whole appearance suggesting the raccoon. In the summer this dog lives on mice and other small animals, and in winter catches fish at such places as broken ice affords. More generally, however, the raccoon dog hibernates, a remarkable departure from the habit of a numerous and widely distributed group of animals. As this dog is one of the least formidable of the family, it is not unfitting that he alone should possess this power peacefully to snooze away the winter regardless of food.

The remarkable intelligence of the wild hunting dogs of India and Africa

India and Siberia and Africa have each their wild hunting dogs. The Siberian representative is a fine-looking beast, and, like its African cousin, hunts in packs. The intelligence shown by the African hunting dog in pursuit of its prey has been noted by many observers, but the Indian dogs are every bit as courageous and as adroit, and are credited on good authority with occasionally attacking and killing both the leopard and the tiger.

If they get a leopard on the run the plan is for two of the biggest dogs of the pack to chase, one on each side of the quarry, while the others pound away in the rear. Every now and again, as if by signal from one of the leaders, the dogs in the rear close in and make a general attack, then draw off. This is repeated again and again until the larger animal is weakened by loss of blood and successive struggles, when the end is not long delayed. This policy of assault and retreat tallies with a description by an African traveler of an attack by a single hunting dog upon a fine sable antelope. The dog would close in and inflict a bite, then hang back for the antelope to continue its flight, keeping close behind, until ready to make another onslaught.

The bold strategy and the audacious cunning of the fox

The fox, with which our chapter closes, is too well known to need much description. Neither is it necessary to produce new evidence in support of its character for cunning and audacity, its skill in evading its enemies and their arts, its bold strategy in pursuit of its prey. That prey embraces the widest range of animal diet — hares, rabbits, pheasants, partridges, lambs, rats, mice, moles; any bird which stealth and swiftness may enable it to surprise; carrion, fish; even frogs, beetles, and worms, as well as shellfish and crabs. To domestic poultry it is a devastating enemy, as every poultry farmer in hunting country knows only too well.

With a diet so varied, reinforced by vegetable additions, the fox was bound to make a bold bid for his place in the scheme of animal life, and he has had a long and prosperous career. His family is almost world-wide in distribution, so that it is easier to mention where he is not represented than where he is. Although unknown to South America, the fox has its home in the northern half of the New World, in Africa, Asia, and in Europe. Australia is excluded from the map of its territory, and there are some islands from which it is a notable absentee.

The fox of the English shire, the African wild, and the eastern desert

But in the desert lands of Asia, in the wilds of Africa, in the frozen wastes of the Arctic regions, in the torrid lands of the tropics, the fox is a well-marked feature of the fauna. The character of its home varies considerably, depending on the animal's surroundings.

Most foxes have a strong scent, and it is by this that they are hunted by hounds, but in India the fox, to a great extent, lacks this tell-tale clue, and so there the greyhound, the dog which hunts by sight and not by scent, is employed. In other lands the fate of the fox trembles in the balance. The fact that he still maintains his ground in many a well-settled country, where he is included among the "vermin," is a striking tribute to his cunning and audacity.

A FOX IN THE BRACKEN

The fox, in his contest with man, has been driven to life underground and when he is to be hunted his "earth" is stopped up at night while he is prowling abroad

There are two or three interesting species of foxes in addition to the common red fox. The desert foxes have a claim to consideration, as reminding us that the desert has still its own fauna. Then there is a small gray fox, ranging from the central United States to Central America, which climbs a tree when pursued, and is said to practise climbing also in pursuit of persimmons and grapes. Arctic foxes, too, are highly interesting animals, notable for their striking change from bluish summer to pure white winter coat, and also for a certain communal instinct which causes them to associate in colonies, where, it is said, they lay up a store of food for winter. The South African fox, remarkable for the extreme length of its ears, seems to mark the dividing line between the foxes and the fennecs — pretty little animals of the Sahara, ranging from Nubia to Algeria The fennec has a still greater development of ear than the chama fox, each ear being as large as the face of the creature, giving a quaint air of intense alertness though there is no evidence to show that its hearing is more acute than that of other foxes

A TRAGIC EXAMPLE OF A PEOPLE HELD BACK BY ISOLATION

The Eskimos, who are an offshoot of the yellow race but are living among the rigors of the Arctic regions, are a striking and tragic example of the fact that the isolation of a people hinders its development and progress

THE DOMINANT PEOPLES

The Passing of the Pure Race, and the Blending of Groups into Great and Dominant Peoples

THE GREAT RACE THAT DOES GREAT THINGS

IN considering the lower or primitive races of mankind, we found them on the whole so well marked and so evidently contrasted with ourselves that no argument need arise as to what we really mean, or are entitled to mean, by the word "race." Our difficulties in that respect are at hand, however; and if we are to discuss the great races with any profit we must face them, especially in view of the fact that modern critics, such as M. Jean Finot, in his "Race Prejudice," are leveling most effective attacks against the older anthropology and its confident pronouncements on the question of race.

Our difficulty is really the same as that which now faces the biologists when they talk of species. So long as forms of animal and vegetable life are far enough apart, the fact that they are of different species is evident, but when we compare forms which are more closely allied, we begin to find that our demarcations break down. Above all do we find ourselves beaten when there has been any intercrossing between the species we are comparing. We may, if we will, ignore the individual mongrel dog or the hybrid pea, but if we find a new species of a new race, or a new variety, we can ignore it no longer.

All men belong, supposedly, to one species, but within its limits we certainly find various races. There is no doubt about it if we compare a negro and a Norwegian, or a Japanese and a Scottish Highlander. Similarly, we may contrast a Russian and a Chinaman, but it is said that if you scratch a Russian you find a Tartar, and it may be a problem exactly to delimit the Tartar and the Chinaman. In other words, our notions of race are imperiled the moment we begin to examine the boundaries between races, for they can only be maintained without fear when we deal with populations that have for ages been isolated. We therefore often find, as the gardener finds, that we can no longer draw the line.

Within recent years, biologists have come to see that the idea of species is an artificial and, in a sense, an unreal one. The studies which are nowadays commonly called "Mendelian" teach us to look upon any individual as a living mosaic, composed of a certain combination of factors. In every individual the exact combination varies, but so long as it varies within certain limits we agree that all the individuals within those limits belong to the same species. Obviously it teaches that, though types may vary widely in some cases, and less in others, there is no absolute break in living nature, and we speak of "species" only for convenience.

If this be true *between* species, much more must it be true *within* the limits of any species, such as man. Indeed, it has not yet been realized how far the Mendelian discovery, and the new conception of species which we owe to it, have cut the ground from under the feet of those anthropologists who still hold to the older ideas of race. Much more do we realize that those older ideas must be abandoned when we discover that, with the exception of very few isolated and therefore backward peoples, all so-called present-day races of mankind are, probably, hopelessly mixed.

"Pure races" of men no longer to be found among the great peoples of the earth

We may suppose that in time long past pure races of man existed. But, at any rate, it is idle to look for such races now, least of all among the dominant peoples of the earth. If we discover men on an island a thousand miles from anywhere, we may have something which we may call a — comparatively — pure race, but to look for such among the great peoples of the earth is now hopeless, and must for many ages past have been just as hopeless.

Man's tendency to wander and to conquer, and the intermingling of conquerors and conquered, which is perhaps the most important effect of war — these have long ago mingled strains of men inextricably. If the process ceased, and all immigration into Ireland or Switzerland or Japan were to be forbidden for a sufficient number of generations, we might expect a definite type of men to be produced by inbreeding and by the particular environment in question, and that we might call a "race." How much the term would mean, and how long the identity of that race would remain if its members were scattered, would, however, be well open to controversy and doubt by scientists and others interested in the problem.

The blend of races which have gone to the making of the Anglo-Saxon people

We do not need to go very far for illustration of the proposition, here advanced, that, roughly speaking, the primitive races are more or less pure, and the great races, so-called, are blends. Assuming for the moment what must afterwards be proved, that the Japanese are one of the great races, let us consider the case of the two little groups of islands, one on each side of the great Eurasian continent, which are inhabited respectively by the Anglo-Saxon race and by the Japanese.

These islanders are now in the forefront of the world. Where, among them, shall we go to discover people of only the purest stock?

Undoubtedly the nearest approach to a pure race in the British Isles and in Japan is to be found among their most primitive inhabitants. Perhaps in the Outer Hebrides, or some such remote part of the British Isles, whose inhabitants are but two or three generations removed from the Stone Age, we might find a comparatively pure stock of people; or on the west coast of Ireland, which contributes inappreciably to the sum total of civilization.

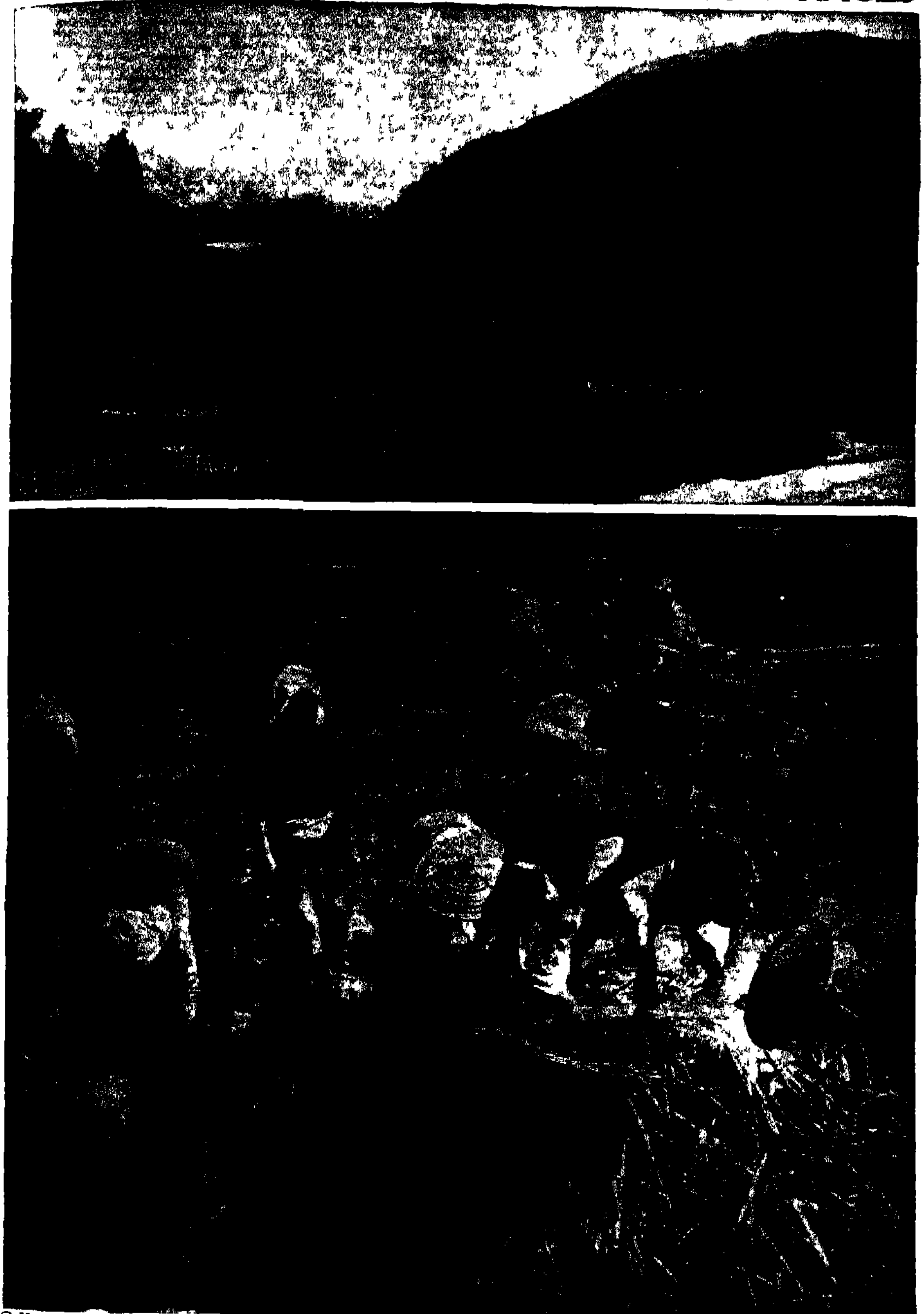
However, the Anglo-Saxon race, which is one of the great races of mankind, we find to be a blend of the primitive inhabitants of these islands, Celts, Angles, Saxons, Danes, Normans, Romans, with a dash of half a dozen other peoples. To call this a "race" in any real sense of the word is ridiculous. It is a blend, perhaps the finest in the world, perhaps not, but a blend in any case.

Compare Japan's case with Britain's. If we want a real race in Japan, we have no choice but to take the Ainu or "hairy Ainos," who are the aboriginal inhabitants of the islands, and may originally have inhabited them, and been confined to them, ever since they were islands at all. But as for the Japanese themselves, they are as much of a blend as we are — Ainu and Chinese and Malay and other strains compose them. The primitive race is relatively pure, the great race is greatly mixed, had the islanders never been invaded and conquered and commingled, perhaps they would be "ancient Britons" and "hairy Ainos" still.

The things that have nothing to do with the greatness of a race

But when all is said and done by way of criticizing the idea of race, good reason remains to study the great races of mankind and to learn all we can about them. We shall learn much more from having examined what we mean by "race" in this connection, and we shall be more likely to face impartially the sociological and political possibilities of the future. And in the first place we must agree as to what people we shall include in the category of great races.

GROWING THE FOOD OF THE YELLOW RACES



THE GREAT RICE FIELDS OF THE EAST, CORRESPONDING TO THE WHEAT FIELDS OF THE WEST

Rice is the staple food of the yellow race It is inferior in nutritive value to wheat, the staple food of the white race. This difference of diet may in some way account for the difference in the characteristics of the two races.

We certainly cannot go by numbers, here or anywhere else. Numerous races, and peoples which comprise but a few thousands or millions of individuals, are worth study for their numbers or their lack of numbers, but this has nothing to do with what we are now considering; for on such a reckoning the negroes would be a great race and the Jews a primitive race. Nor can we go by color of skin, for that is but skin deep, and we are dealing with man, who is essentially man's brain, not man's skin. Buddha was brown, and belonged to an indubitably great race; Jews may be almost black, or blue-eyed and fair; the Japanese are yellow and the English white. Stature, type of hair, jaws, trunk, and so forth — all these fail us.

We can learn something from the capacity of the skull, but not very much, for brains may be much folded in small skulls, or less folded in large skulls, and it is the extent of the "gray matter" that tells. With the older anthropologists, we may divide men according to whether they are short-headed or long-headed, or neither short nor long-headed, and may give the palm to the particular type of head which we possess ourselves, as there is reason to suppose has been the anthropological practice; but if we find that skull-form changes in a generation or two in changed environment, what sort of calculations can possibly be built upon such foundations?

Evidently there is only one test by which we can distinguish the great races: "By their fruits ye shall know them." A great man is not one who fills a great place, but one who does great things. A great race is not necessarily a numerous race, nor a powerful race, nor a large or a small, nor a long-headed or a broad-headed one. It is a race that does great things.

This, of course, merely raises a new question — what are "great things"? Thus for many ages the Japanese had a highly developed society, noble traditions and practice, a high standard of family life, a culture which was notable in poetry, unrivaled in the garden, unique and exquisite in art.

Yet it seems no one took any account of them. Later, they repealed the laws whereby they had so long guaranteed the isolation of their country, copied European ways, and achieved success in the arts of machinery and warfare probably at the cost of much of their characteristic greatness. They were immediately reckoned a great race.

The greatness of the yellow race in the serious things of life

The case really does not need any sort of argument, since we are now all agreed as to the Japanese title to inclusion in that category; but a pretty problem might arise if we were to meet a race which was like the Japanese of 1850. This is precisely the difficulty which might have met us in the case of the Chinese, but they are so numerous that most people will grant their greatness on that account.

There is, indeed, no reason why the yellow race should not be considered here as a representative example of what we mean by a great race. This race is not only great on account of its achievements in civilization, in philosophy, in ethics, and in science, but it is certainly great in numbers, if that be taken into account, for it is much the most numerous race in the world. It appears from the most recent census that the population of China has been considerably over-estimated, but, even so, the yellow or Mongolian peoples outnumber any other.

The various members of this race conform to a certain physical type, though they differ from one another in various parts of the world no less than do the members of the so-called "white race." The Chinese may be tall as compared with the Japanese, but both have a yellowish tint of skin, straight black hair, prominent cheekbones, and the oblique Mongolian eye — which last, however, is only present in a much smaller percentage of these people than we commonly suppose. They have themselves contributed to the general impression that all yellow people have this peculiar structure of the eye — or, rather, of the eyelids — by having emphasized it so long and consistently in their art.

Caricature is almost never absent, however, from Chinese and Japanese representations of the human face and person, and the Mongolian eye is neither so constant, nor, when present, anything like so marked in reality as Mongolian art would lead us to believe.

The appearance of the Mongolian eye in members of the white races

It is a fact of much interest, hitherto wholly unexplained, that members of the white race are occasionally born with well-marked Mongolian eyes. These individuals are sometimes the last of a very large family, the members of which have been born in rapid succession, with much consequent exhaustion of the vitality and strength of the mother.

The brain in such cases develops imperfectly, and the result is a wholly incurable and hopeless form of mental defect which is known as "Mongolian idiocy," in allusion to the most obvious characteristic of the face It need hardly be insisted, however, that Mongolians are as intelligent as any kind of human beings, and the moral of the case is to beware of judging by externals. These afflicted people have the Mongolian eye, but anything rather than the Mongolian brain, which is of a very high order

THE MOST NUMEROUS FAMILY OF THE MOST NUMEROUS RACE IN THE WORLD

The principal members of the yellow race — which is really, of course, the yellow group of races — are the Chinese and the Japanese, who, between them, constitute the great majority of its units.

The barrier to the progress of a people isolated from the life of the world

Very great interest attaches, nevertheless, to at least two supposed offshoots of this race, none the less because we shall not find it easy to recognize the greatness of the race as these illustrate it. They are the Eskimos and the North American Indians. The indigenous human inhabitants of the North Polar region, and of the New World, are thought to be derived from the yellow stock. They scarcely exhibit more evidence of greatness than is shown by their boldness and hardiness in leaving their warm Asiatic home for such distances and solitudes and rigors.

In them we see illustrated the proposition that isolation of a people, as of an individual, puts a barrier to progress. This does not mean, for instance, that the solitary student cannot progress. He may merely resign the company of the living for that of the dead, namely books, which, if well chosen, are usually so very much more alive. Isolated from books, however, or from his memory of them, the solitary man reverts inevitably to the primitive state. So with an isolated people, or with any isolated class among a people, they cease to progress, or may actually revert. Be it noted also that such a people as the Eskimos have, by the very condition of their life, set themselves too hard a problem for mankind.

How the vital energy of the Eskimos is spent in maintaining mere existence

If really descended from tropical or sub-tropical forms of life, they have advanced not merely to the temperate zone, which has witnessed the whole of man's triumphs, but beyond it to the Arctic confines, where the organic life of man, still demanding a blood temperature of 37.5° C., can only be maintained at the sacrifice of almost everything which is more than organic.

We know the vital energy has to concentrate itself upon resistance to cold and maintenance of heat by the deposition of much fat under the skin, by the absorption and digestion of very large quantities of food, notably fatty food, with which the human stomach cannot deal at all, and which requires so much time and energy for its proper and complete digestion.

The Eskimo branch of the yellow race thus teaches us one-half of the vastly important truth that the conditions of human existence may be either too hard or too easy. Mankind near the Poles provides us with one illustration; mankind in the tropics, where never yet civilization was to be found, teaches us the other. But when we consider the Eskimos, and the influence of conditions, let us beware of the modern error of attributing everything to race, as if life were not an adjustment between the actual organism itself and its environment.

The human virtues richly represented among the North American Indians

The North American Indians obviously partake in several respects of the characteristics of the yellow race, though the Mongolian eye is less to be found among them. The skin color is indicated by the term "Red Indians," and we are familiar with the character of the hair and the cheekbones. Here, also, is a branch of the race which has been isolated and subjected to excessive rigor of climate and hardships in living conditions.

We find, however, that those who have traveled with Eskimos to the North Pole, as Peary did, and those who have acquainted themselves intimately with the American Indian, are agreed that the most notable of human virtues are richly represented among both these peoples, and it is probable that no one has more admirably developed his senses and his intelligence for solving the practical problems of life than the Indian, whose observation, courage, resource, memory and inventiveness have won innumerable tributes from travelers from all parts of the world and representative of many races.

"THE PARLIAMENT OF ST. KILDA" — PRIMITIVE INHABITANTS OF THE BRITISH ISLES

A FAMILY IN LAPLAND, SHOWING HOW A MOTHER CARRIES HER BABY

All men belong to one species, but within its limits we find various races. There is no doubt about this if we compare such types as are shown in these two pictures.

A serious responsibility devolves upon the United States in regard to the remnants of this remarkable people, the pioneers of mankind in the western hemisphere; and it is good to believe that the appalling ravages wrought by tuberculosis and alcohol in the past appear to be within reach of an end, and that, under the conditions of the present day, the number of these people is actually showing some increase. They may yet play a notable part in pushing the limits of civilization as far north as nature's restrictions will permit this to be done.

What may happen if the yellow races should eat wheat instead of rice

In qualifying with modern knowledge our notions of race, we must recall the notable fact that the chief representatives of the yellow race live mainly upon rice, whereas white people live mainly upon wheat. It is certain that rice is inferior to wheat in nutritive power, and it may be more so than has until lately been supposed, seeing that minute traces of certain compounds in the wheat grain are of such high importance for the highest human development.

There seems reason to suppose that the substitution of wheat for rice in the diet of the yellow race, or the inadequacy of the world's wheat supply to feed the white race, might notably modify, in various directions, the characteristics and destiny of the two races, as wheat has the more "vitamines."

In this connection it is interesting to note that the modern Japanese are adding meat and milk in large quantities, as well as wheat, to their diet. It will be of notable interest to observe the possible consequences of this modification of diet upon the supposedly *racial* characteristics of the Japanese. Students of the wheat problem and of the dietetics of wheat, will also be concerned to note the influence upon the Chinese race which might conceivably be exerted in the near future should Siberian wheat find Asiatic, instead of European, mouths to swallow it. From the awakening of China this now appears highly probable.

Certainly, and in any case, the yellow race, taken as a whole, will play one of the leading parts in the future of mankind; and the nature of that part, for good or for evil, will ultimately depend upon the racial character, physical and psychical, and upon the degree and direction in which it may be modified by change of diet or habit. This is not a race which is slowly disappearing; it is not a scanty race; it has nothing to fear as a whole — unlike its scattered offshoots — from the devastating influence of our civilization, with its diseases and its vices. The Tasmanian, the Australian aboriginal, the American Indian, the Maori, and many more may be all but ignored for the future, on one ground or another, even granted that their native potentialities are high; but the Chinese and Japanese are too numerous and too fertile, and they have too long had a civilization, with overcrowding and infectious disease, and narcotic drugs of their own, to fear contact with ours as so many other races have had reason to do. There they are, and there they will remain, or, rather, there they will not remain, for they will certainly spread; and there is no sign or shadow of any power on earth that can ultimately say them nay.

The effects of intermarriage between the white and yellow races

Evidently the problem of intercrossing has to be faced, as it has had to be faced a thousand times already in the history of mankind. Race-prejudice, race-hatred, instinctive race-antipathy are to be allowed for, but not more than their due. No antipathy exists between, for instance, European men and Japanese women, though it is stated still to exist between European men and Chinese women. Familiarity is most potent in this sphere. The possibility and consequences of intercrossing between the white and the yellow people have to be faced.

Experience hitherto is but fallacious, it is too scanty, and it has not been obtained under fair conditions. If the problems of racial intercrossing are to be solved in any fashion satisfactory to science, two primary conditions not yet met must be satisfied.

The nurture, including education, religion, social consideration, and opportunity, of the resulting children must be the same as that of children of single racial origin. If this condition be not satisfied, obviously the experience is vitiated as an "experiment," and nothing can be argued from it. Secondly, the intercrossing representatives of the two races in question must really be, in the broadest sense of the term, representative of their respective races.

PRIMITIVE INHABITANTS OF THE BRITISH ISLES — PEASANTS OF THE WEST OF IRELAND

The great races of mankind such as our own Anglo Saxon race, are not pure single races but blends of several. The nearest approach to a pure race in the British Isles is to be found, perhaps, among the inhabitants of the Outer Hebrides or the West of Ireland.

For if, say, the father be a white man who has left his country for his country's good, and, say, the mother be a yellow woman of indifferent moral character and habits, what of value as to the consequences of racial intercrossing can possibly be argued from the children? Yet such, too often, has been the kind of parents from whose children such sweeping anthropological generalizations have been inferred — parents who may be justly regarded as wholly unrepresentative of either race in question.

Science knows nothing against the joining of two "equal" races

Here, since science is our object, we make no assertions, in the absence of the necessary experience; but in the name of science we repudiate such experience as cannot serve science, except to the extent of showing that children who live under a slur, or children of indifferent parents, are unlikely to turn out well. Racial intercrossing is not required to prove such propositions, and the available illustrations prove nothing as regards this.

All that science can venture to assert, so far, is that, granting the natural equality of two races, nothing is known in the scientific sense of knowing, which entitles us to expect that the children of two such races should be naturally inferior to the children of either. On the contrary, they may even be superior to their father's and mother's stock.

The yellow race is not the only great race in Asia. The records of Indian civilization are conclusive on the point. In northern Asia, as we should expect from our observation of the American Indian and the Eskimo, the conditions are too hard for greatness, or at any rate for recognizable greatness. In the southernmost portions of land commonly reckoned with Asia, the conditions are tropical — too easy, and therefore, in the long run, too difficult, for the maintenance and nurture of greatness. In intervening zones, as in northern India, the records of philosophy and art and legislation need no qualification, even if such supremely great teachers as the well-known Buddha had not been of Indian origin.

Here we have a race, or rather a great mixture of races, which is not yellow, and is not white. Its affinities, many will tell us, are European; and, indeed, men still speak of the Caucasian, Indo-European, or Aryan race, in which are included such apparently diverse forms as, say, the Swede and the Hindu.

How far does language go in marking the boundary line of races?

To the biologist or the modern anthropologist this is perilously near nonsense. If the word "race" is to have so wide a meaning, it has no meaning, and had better be abandoned. But the contemporary student will be left without a key to the mystery unless he realizes the history of these notions.

The evidence on which most accepted ideas of the great races are founded is derived from language. Philology, or the science of language, recognizes affinities between this tongue and that, and fundamental differences between both of them and a third. These differences may be profound. It is not a long step from northern English to Dutch, but that from English or Dutch to Chinese is almost measureless. The whole genius, as we say, of the two kinds of language, the whole theory of them, their growth, structure, grammar, alphabet or absence of an alphabet, are incalculably different in the two cases.

Contemporary philologists, notably represented by Professor Max Müller, put up this fascinating science, which may well claim high importance, dealing as it does with man in his all but highest and most characteristic attribute. In doing so, they incline to argue from language to race. They group, classify, compare and contrast languages, assume a correspondence in race, and a similar or single racial origin for two sets of people, each of whom has the same type of language, or uses the same, or practically the same, words.

Tracing race from similarity in language impossible of constant application

We can all see that there must be something in this. Evidently the similarity between older forms of English and Dutch goes with the largely common origin of the peoples in question, and so on. The question with such a theory, however, is how far does it go? And this question is answered by modern anthropology with no uncertain voice.

Evidently such a theory as this of the philologists cannot be of constant application. Languages are adopted, languages are imposed, convenient forms replace inconvenient forms, conquerors insist on the substitution of one tongue for another, and then, perhaps, disappear, while the alien language remains, seemingly native to the race upon which it had been imposed. Furthermore, men are men, and a brown man in India and a white man in England may put notions together similarly in similar circumstances, without its following that they both belong to the Indo-European race, or that such even exists.

It is certain, in a word, that the philologists carried their theory too far; and that is one of the reasons why, with advancing knowledge, we are so much less certain about matters of race than men were a generation ago, when all that was needed was to compare language, and the questions of race settled themselves. All homage, nevertheless, to philology, past and present, and to its future services, even though we expect these to teach us more about the human mind, and less about racial types of body, than used to be supposed.

Let it suffice, then, that many brown people inhabit India and its neighborhood, that they are on the whole nearer to us in many ways than are yellow people, and that they number great races as well as primitive. Here, again, we may observe that pure and primitive races are those which are isolated.

The great race of people who do not possess a native land

Wandering about the earth, having no native land, we find a strongly marked kind of people, not even to be included in the most comprehensive term of "Indo-European," whom we have termed the Jews.

THE AMERICAN INDIAN AT HOME—CUT OFF FROM THE GREAT BODY OF THE RACE IN ASIA

The American Indians, who belong to the great yellow race and have been the pioneers of mankind in the Western Hemisphere, have been greatly hindered in their development by being isolated from the great body of their race

Now the most primitive people in the world are the Veddahs, the aboriginal inhabitants of the hill country of Ceylon. Indeed, it is difficult to speak of them otherwise than in such terms of pitying contempt as the more humane of the Roman authors used when describing the isolated islanders whom they encountered on the southern shores of England.

They may be any color, perhaps because they have lived for so many ages in every kind of climate. In the south they are tanned and colored by the sun, and thereby protected from its rays, just like their neighbors, whereas in the north they are often quite fair. That they are definitely an Oriental race is a point on which we may agree.

Jewish race peculiar because of its ubiquity, characteristics, small number

The reservation must be made that all races are ultimately Oriental — if man was not born in Europe. But the Jews are more recently Oriental than the contemporary Occidental peoples, among whom so many of them dwell. They demand attention here on many important grounds.

The Jewish race is peculiar because of its ubiquity, its strongly marked racial characters, its number amounting to perhaps no more than ten or twelve millions today — yet was never so numerous as today — and its unquestionable claims to moral and intellectual greatness. Conspicuous in no art save music — though the modern painter Israels is an exception — and deficient in many qualities which are or may be made admirable, and notably in those which show themselves in great political achievement, and in war, and in the mastery of nature, the Jews are nevertheless preëminent in other directions, having given us the noblest monument of ancient literature, and having provided modern civilization with its dominant religion.

Will the future witness the disappearance of the racial identity of the Jew?

Conspicuous in Jewish practice has been the avoidance of intermarriage with other peoples. For good or for evil, this has undoubtedly been the cause of their close approach to racial purity of today, with its pleasant and unpleasant, admirable and less admirable features. They have been in the Gentile world, but not of it. They have made all manner of terms with their conquerors, have accepted indignity, servitude, ignominy, exclusion from all manner of pursuits and possibilities, everything but the degradation of their women; and they have kept their blood practically pure. If man at large did not require every line of space that can be spared for his consideration, more might well be said about this race, in speaking of which even the modern anthropologist can scarcely feel that he is describing a fiction.

Dr. Maurice Fishberg, a recent authority, reports the gradual breaking down, in such great centers as New York, of the Jewish prejudice or canon against intermarriage. All modern influence works in this direction; and the future may witness the disappearance, as a racial identity, of this remarkable people, if it should not happen that the Zionist gives them a country of their own, and permits their independent development there.

Color will probably long remain the best defined distinction between races

The great branch of mankind which we call the white race remains to be considered. We describe it by its color, though that involves many difficulties. If we attempt any other definition of the races of man, we find, however, that the difficulties are at least as great, and it is therefore probable that the "color-line" will long remain the best defined between races of man, even though the case of the best marked of all races, the Jews, shows how little that line is ultimately worth.

The white people of the earth inhabit its temperate climes — an incalculable advantage for their development, as we have already argued. Relatively they are, of course, white, though wide variations are to be found between, say, Swede and Sicilian, even allowing for the possible negro admixture in the latter. But it is to be noted that the white peoples are not really white — that is to say, the skin is not colorless. As stated before, only abnormal and morbid specimens of mankind, called "albinos," are really white. The color of the white race is to be found not merely in the iris of the eye, but also in the upper eyelids and in other parts of the body much less exposed. In all parts of the body, exposure to certain constituent rays of sunlight will excite the pigment cells of the skin; and in many Anglo-Indians the exposed skin may be as dark as that of many natives. Within the limits of the so-called white race it is therefore not unnatural to find at least two well-marked varieties, distinguished by their degree of coloring-matter, whom we call "blonde" and "brunette."

Such a division will naturally raise many interesting questions, for students report that the blonds do not withstand well the processes and risks of civilization, and that, on the whole, they are dying out and being replaced by the brunette or darker type. If it should prove that the blonds have characters of mind which are more or less their own, and which have a permanent value, this alleged decadence of the type is much to be regretted on other grounds than that of their undoubted beauty.

Many theories advanced to account for asserted disappearance of blond type

There is substantial ground for the argument that it takes a race a long while to become tolerant of the artificial set of conditions which we call civilization. The Jews are the only known example of a race which can survive civilization in the strict sense. The Chinese can do so, but with what necessity for incessant replenishment of urban by rural blood we cannot say. In Europe, Jews excepted, the rule seems to be that the cities consume what the country produces, not only in the way of food, but also in the way of men. According to some recent observations, this destructive process seems to tell more hardly upon the blonds, who seem to be the descendants of the more northern peoples, whose acquaintance with cities and their conditions is more recent than that of the darker dwellers near the Mediterranean. Some such explanation might be advanced to account for the asserted disappearance of the blonds in modern civilization.

At any rate, the white race remains, though it may thus tend in the future to consist of its browner representatives. Its characteristics need no special description, for our description of other races usually implies a description of ourselves as not peculiar in such and such other respects. The white race, if we include therewith such Orientals, all originally dark, as the Jews and the ancient Greeks, has brought the modern world to its present state of perfection, and it remains to be seen to what extent it will be sole arbiter of its future.

All of the succeeding sections of our study will normally deal with this race simply because it is the race whose members have been chiefly, almost exclusively, studied, alike as regards the skeleton, the muscles, the senses and the intelligence. A vast field remains for work in studying the various races of mankind, primitive and great, with as much detail and thoroughness as has been done in the case of the modern European. Man cannot be too carefully studied in all his forms, numerous and rare, pure and mixed, simple and complex.

Hereafter we study man in general, referring scarcely at all either to racial or to individual differences. We have said enough, however, to show that the racial differences exist, and it must never be forgotten that the individual differences exist also. It is certain that within the limits of any race we find much greater differences in such essentials as intimate brain structure than exist between average types of different races. This proposition clearly involves the necessity of recognizing that we require a more detailed study of individual men than ever before. As we argue less and less confidently about race, and even become doubters as to the worth of racial studies which simply mass men together and take the average of them, we become more concerned to study individual men and women, of all races, at all ages, and under all conditions, realizing the amazing variety of our kind. The old method of studying many specimens in some particulars, and taking the average of them, has broken down. The cruder statistical methods, and the more refined ones, termed "biometry," produce results which do not withstand the criticism which study of the individual involves; and the advance of Mendelism has taught us, as never before, the futility of arguing about races until we know more about individuals.

These considerations are earnestly impressed upon the reader, by way of caution, before we start to speak in detail of "man," as if all men were as "alike as two peas" were supposed to be, until Mendel *found them to be quite different.*

NOONDAY REST ON THE OPEN ROOF OF A SCHOOL

A GOLDEN RULE OF HEALTH

Why we must Breathe through the Nose and Why we need not be Afraid of a Good Draught

SHUT YOUR MOUTH AND SAVE YOUR LIFE

THE policy of the open window is good, the policy of the open door is better, but the policy of the closed mouth is best. Of all aspects of health this is the chief.

The first of all health proverbs is — Shut your mouth and save your life. Unless you have something to say or to swallow — and very often even then — your mouth is best shut. The breath of man was planted in his nostrils, and there it should remain.

But how about those who cannot breathe freely through their noses, and who therefore cannot obey the first law of health?

A considerable and growing percentage of all our city populations now suffer from adenoids and the consequences of adenoids. Compulsory medical inspection of school children has justified those observers who had declared that this was a great national evil, and that it was affecting more and more school children. Though adenoids are found in all parts of the country and the city, they seem to be specially associated with city life. The immediately existing cause of the complaint is probably dust — and may prove to be dust of a special kind, containing special microbes. This dust, as a rule, causes colds in infancy and very early childhood which lead to the morbid overgrowth of tissue at the back of the nose and throat which we call adenoids.

The experts in this subject distinguish between adenoid growths at the sides of the nose, which interfere with the hearing, and "central adenoids," which interfere with breathing. These are the commonest form, and these alone concern us here. They are the chief cause of inability to breathe through the nose. To them must be added a very common defect of the nose, which consists in a displacement or deflection of the partition between the two nostrils. This means that one nostril is largely obstructed, and the deflected partition usually provides, at some kink or other, an admirable breeding-ground for microbes.

Children with adenoids, or with a deflected nasal partition, are exceedingly liable to colds, and in the course of a few years these colds do further injury to the lining of the nose, and not least to certain parts which have the special duty of purifying the air as it passes through. The state of these young people thus goes slowly from bad to worse. They become more and more liable to colds, sore throats, attacks of laryngitis and bronchitis, and many of them begin to get wheezy in their chests, and show signs of asthma. Some of them also, especially those who live in the country, become very liable to hay fever. All these points have to be added to the bare fact, which is serious enough in itself, that they are largely or wholly compelled to breathe through their mouths.

The mouth has therefore to be kept open, giving a foolish and weak appearance to the face. This appearance of stupidity is reinforced and justified by the child's mind. It is not getting sufficient air into its blood, and — far more important, though forgotten by most people — the child is being constantly poisoned by the microbes which settle in its nose, and by those it breathes through its unguarded mouth.

The breathing through the mouth which vitiates and stunts a child

Adenoids may disappear as the child grows older, and parents will often hopefully wait for this to happen while the child is being half suffocated and half poisoned all the time, and while its growth is being stunted, and its development vitiated for life. The general rule is that the adenoids do not disappear; and as for the troubles due to a misshapen nasal partition, they are cumulative and uncontrollable so long as that partition remains where it is.

Every doctor knows a "mouth-breather," and what the future history of that mouth-breather tends to be. But only the experts yet know that this condition of mouth-breathing, due to nasal obstruction and the presence in the nose of disease which converts what should be a filter for microbes into a breeding-ground for microbes, is one of the chief predisposing causes, as we might well believe, of infection by the microbe of consumption.

The great harm that may be done to children by the prejudice against surgery

Modern surgery can remove adenoids with speed, completeness, and safety. It can even deal radically with defects of the nasal partition, though this involves a substantial operation and a fortnight's "holiday" for the patient, and no one should nowadays permit the continuance of nasal obstruction in himself or in anyone for whom he is responsible.

Surgery alone is the remedy for these conditions, and for all the evils which flow therefrom. It is probable that in no respect does the popular prejudice against surgery, and fear of even the simplest and most trifling operation, do more harm than in its interference with the performance of the simple one for the removal of adenoids from children's throats.

Now we may amplify our dogma, and say that the very first condition of perfect health is to breathe through a healthy nose. Allowing for heredity and its decrees, we may fairly say that this is beginning as near the beginning as the individual can.

The reason why we should breathe slowly through the nose

One must breathe through the nose because it moistens, warms, filters, and even to some extent sterilizes the air. The mouth can do none of these things, all of which are important, and some of which are absolutely essential. The nose exists for these purposes. Life is intensely economical, and constantly employs one structure for as many purposes as possible. If to admit air freely were the whole requirement, we should use our mouths for that purpose, and we should not possess noses. It is not the whole requirement; indeed, to have too free and clear a nose is almost as bad as to have an obstructed nose. If the air be not compelled to pass slowly enough through the nose, it will not gather enough moisture, nor be sufficiently filtered of dust and microbes; and the tonsils — which are auxiliary to the nose — will probably prove inadequate to protect the voice-box, the windpipe, and the lungs from the effects of dust and infection. We see people using respirators, and we hear of the filtration of the air which enters modern theaters or lecture rooms. But every one carries with him, if in health, an efficient respirator and filter, which he must continue to use at his peril. If it gets out of order, it encourages infection, which leads to its own degeneracy, and later to the infection of still more important and vital organs. No child or adult with an unhealthy nose is safe, and yet the remedy is so simple.

The serious infectious disease that we call a "common cold"

So much for this most important subject, and now we shall see that it has prepared us for the study of a new subject, which we could never have understood if we had not dealt first with the nose. That new subject is the too familiar one of "catching cold," and the whole question of draughts and protection from them. Now, we must understand, once and for all, that a common cold is an infectious disease, due to particular kinds of microbes, just as definitely as is cholera or mumps.

The healthy nose very rarely contracts this particular infection, just as the healthy stomach very rarely, or never, contracts infection by microbes that attack it. The healthy stomach produces a powerful antiseptic, hydrochloric acid, which kills microbes. The healthy nose produces a mucus which is also definitely, though not highly, antiseptic; and, further, all parts of the healthy nose are perfectly drained, and there are no odd corners where the mucus stagnates, and in which microbes can multiply. The best way in which to avoid the disease we call a cold is therefore to have a healthy nose; and if one has not a healthy nose, no precautions will prevent one from contracting colds, or worse.

It may be argued that, if the nose runs these risks, it would be better to breathe through the mouth. Not at all. Microbes and dust instantly strike the back of the throat, which is continuous with the back of the nose, and in all other respects one is worse off than before. There is no remedy but to acquire a healthy nose, and then to breathe through it.

The hidden perils that face us all in our daily lives

But, of course, there are limits to the resistance of any vital organ, and we must not suppose that our duty, as regards colds, ends here. Anyone may meet particularly virulent microbes of certain kinds, and acquire a cold, just as anyone may meet particularly virulent microbes of other kinds, and acquire cholera or leprosy. Here, as in all other cases, our duty is twofold — to protect ourselves against infection and to avoid it.

Now, where is the infection of colds to be found? For instance, comparing the closed street car or inside of the bus to the open car or top of the bus, where is the infection most likely to have been deposited, and where is it most likely to remain? If we think of "catching cold," then we shall vote for the closed street car or inside the bus as safest; if we think of avoiding the microbes, we shall vote for the open street car or top of the bus as safest. Our answer entirely depends on how we put the question.

If we think of microbes as real and palpable, like mad dogs, fleas or wasps, or any other form of visible life that we object to, we shall very soon look upon the inside of closed public vehicles as, so far as possible, to be avoided.

The ills that flesh is heir to when weakened by "cold"

Of course, this is not the whole story. Whatever a "cold" may be, there is such a thing as cold, and its devitalizing effect is beyond question. Pasteur took a fowl, an animal which is normally immune to inoculation by the microbes of anthrax, and stood it with its feet in cold water. Thereafter the fowl was found to be susceptible to inoculation. Its immunity had broken down under the influence of cold. So there is something in the theory of "catching cold," after all.

Quite so, but we must be sure that we understand what that something is. People sometimes read this experiment as if it proved that its cold feet had given the fowl anthrax. Not a bit of it. What gave the fowl anthrax was the bacilli of anthrax, to which the cold had rendered it susceptible; but a fowl or a sheep might have its feet in cold water for all time without contracting anthrax, or any other infectious disease, if the infective agent were not present.

Is it true that we cannot catch cold from sea-water?

And now we can interpret the well-known fact that "people don't catch colds from sea-water." It is true that we go to the seaside, and bathe, or wade, or even get our feet wet through our shoes and stockings, and get splashed with spray — and don't "catch cold." The real explanation is simple enough. Even though we have been in the water too long, and have really lowered our vitality, just like Pasteur's fowl, we don't catch cold because the experiment is not completed — the inoculation is not made. There are very few germs of a cold at the seaside; none at all on the beach, and very few in the houses, as a rule, and we are out of doors most of the time.

The result is that we no more catch cold than we catch hydrophobia in the absence of mad dogs. Moreover, as a rule, our exposure to sea-water is not severe enough to devitalize us, but proves to be a tonic, and even if we did encounter the germs of a cold we should be fitter to resist them. And it may be added that the salt in sea-water when we bathe or wade is a stimulant to the skin, and helps our health, just as the motion of open air helps our health by giving a kind of tonic "fillip" to the skin. But beyond question the chief and sufficient explanation why exposure to cold sea-water, even over-exposure, does not give us colds is that the germs of the colds are usually not there.

Why we often catch cold on coming back from the seashore

One unfortunate fact may be added about sea air or country air for the city dweller. It is very often noticed that, though we enjoyed our vacation, got wet through, and exposed ourselves over and over again, and caught no harm, when we get back to town we promptly catch severe colds. The fact is only too familiar to many people. Apparently the pure air was too pure — in the sense that we lost our faculty of resistance to dust and its contents, simply by lack of practice. When we get back to the city streets, and our noses are filled with dust and microbes again, after an interval they are very apt to succumb, which is quite understandable. It may often be, also, that we return home, only to be attacked by germs which have been multiplying there in our absence — unless we were uncommonly wise in having our house or flat properly cleansed and aërated and illuminated by the sun in our absence. Of course, if we exclude air and sunlight, and stop dusting and sweeping, we must expect to find something lively and deadly lying in wait for our return.

As for street dust, with its abominable and offensive contents, undoubtedly the disappearance of the horse will do much for its improvement in coming years. It is a public nuisance and a private danger to the throat and nose and eyes.

The germs of disease that are allowed to float about in cities

The best thing about the night air of cities is that it is less "streety" than day air. But city dust is not objectionable in the streets alone. It sadly compromises the policy of the open window by making that policy involve the reception, along with fresh air, of quantities of dust and dirt, and microbes and soot, which vitiate the air, make everything dirty, clothes and curtains, and books and all. It is certain that, in a short time, popular opinion will be sufficiently educated in these matters to demand that streets shall be more thoroughly cleaned and kept cleaner and less dusty than heretofore.

Meanwhile, the policy of the closed mouth is more urgent than ever. The more dirty and dusty and microbic the air, the more essential is the filtration which the nose alone can effect for us. At times, in the streets, we may encounter unpleasant odors, which tempt us to hold our noses and breathe through our mouths instead. This is quite a mistake. The smell is indeed a warning, and should be acted upon, but by getting away from it, not by exposing ourselves far more gravely to the infection that accompanies it, which is what the rash policy of the open mouth amounts to.

The words of the wise king — "He that keepeth his mouth keepeth his life"

The most fearful of all microbes in this country is the tubercle bacillus, the cause of consumption. Wise fear of this germ enforces, more than all other considerations, the policy of the closed mouth. At present, consumption is hideously neglected in many countries, as every one would admit if the disease commonly killed in seven hours or days instead of years; and the consequence is that its microbes are very frequently encountered by probably every one of us.

We meet them in the open street, to some extent, but far more in street and railroad cars and places of public amusement, and most of all in places where men spit.

Until this most deadly of diseases is abolished, the careful citizen will keep the door of his mouth more closely than ever, reinforcing with the science of Pasteur and Koch the words of the wise king: "He that keepeth his mouth keepeth his life!"

The kind of draught that does good and the kind that does harm

It is right, in considering the policy of the open window, that we should know the truth about draughts, and, on the whole, there can be no doubt that draughts do immeasurably more good than harm. We should remember that the injury done by a draught depends upon its local intensity. It follows that to open the window six inches may be risky, but to open it as far as it will go may be safe. The safe way, and the comfortable way, in which to practise the doctrine of the open window is to make one's room, as far as possible, part of the open air. Instead, we try to compromise; and though entire exposure to the open air would have done us good, we suffer from admitting a narrow streak, which is in the form of an acute draught.

The hygienist may really hope, however, that his arguments will soon be rendered superfluous by the automobile. The tremendous growth of automobiling and in the number of privately owned cars and motor-cycles is teaching all sections of the population that their ideas about draughts and colds, and their fear of the open air, even in the form of intense — but *broad and copious* — draughts produced by motoring, were ill founded.

Why plants are good in a room by day but bad by night

The action of plants upon the air cannot be entirely neglected by the hygienist. During the daylight, green plants absorb carbonic acid gas from the air, and give out oxygen. They therefore directly ventilate the air, though in exceedingly small degree. At night, however, the state of things is reversed. At night the plants no longer decompose carbonic acid, but merely breathe, using up oxygen and producing carbonic acid.

Growing plants are therefore desirable companions in living rooms, and by day in the bedrooms of the ill, but they should be removed from bedrooms at night.

What has been said about dust will suffice to prove that rooms should not be dusted or swept in the ordinary way, but with the aid of a vacuum-cleaner, or a carpet-sweeper, or in any fashion whatever provided that no dust be raised. In a few years we shall marvel at the fashion in which we used to clean our rooms. And similarly all the sweeping of city streets should be preceded by the use of water. If there be any city where streets are now dry swept, raising huge clouds of microbe-laden dust, it should be made known as a town unfit for human habitation.

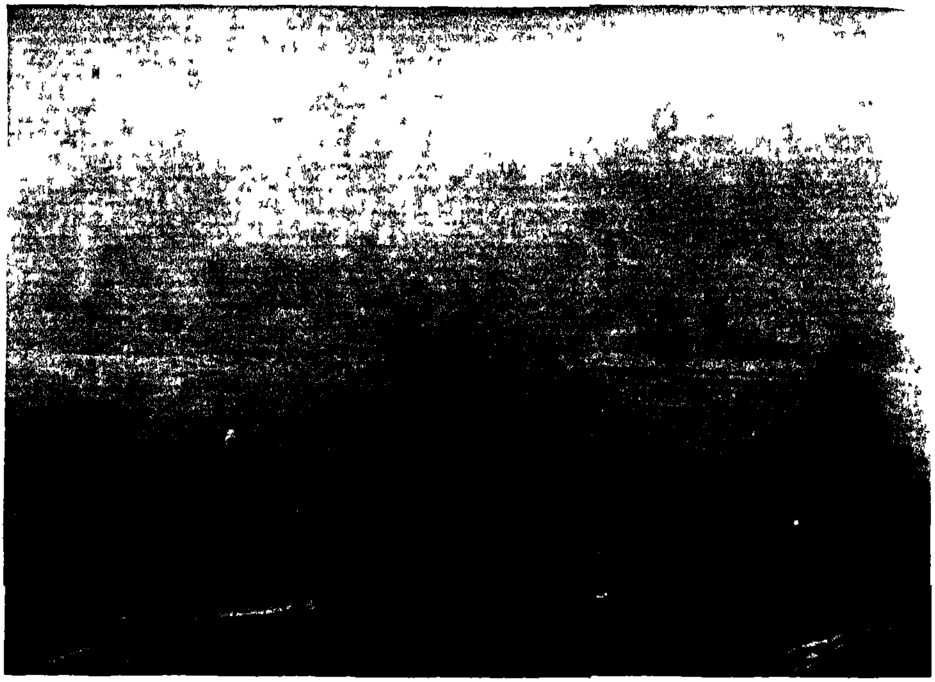
The questions of weather and climate are, of course, connected with the problem of air, but they introduce so many other considerations that they require to be dealt with separately. But there is one important point to which we must refer.

How we may get used to the dust of the city and adapt ourselves to it

This point is the great fact of adaptation and its laws. We have already hinted that one may become unaccustomed to city air and dust, so that, on return from an excellent vacation, one may yet be knocked down by a "cold." There is no doubt that we can and do acquire a great deal of adaptation and resistance to atmospheres which are short, often far too short, of perfect. This adaptation works in all directions, and if it is to be successfully carried out it must be sufficiently gradual. The convinced and enthusiastic reader is urged to adopt the policies of the open window and the open door and live in the open air as much as possible, but he should do so gradually.

As for the supposed adaptation of the slum populations of our cities to the slums, and the breeding of a slum race to which slums do no harm, it will be time to discuss that when we find the race to which slums do no harm; and the hygienist is inclined to wish for a few concentrated samples to silence those who apologize for what is so immeasurably beyond apology.

AN ANNUAL CITY SAVING OF $2,500,000



ONE OF FOUR CONSECUTIVE DAYS IN 1914 EVEN THE STREET LIGHTS HAD TO BE KEPT BURNING

Photos Bureau of Smoke Regulation of the City of Pittsburgh

VIEWS OF PITTSBURGH BEFORE AND AFTER THE ABATEMENT OF THE SMOKE NUISANCE

THE USEFUL WASTE

How Cheaper Power is Being Won and Untold Riches are Extracted from Waste

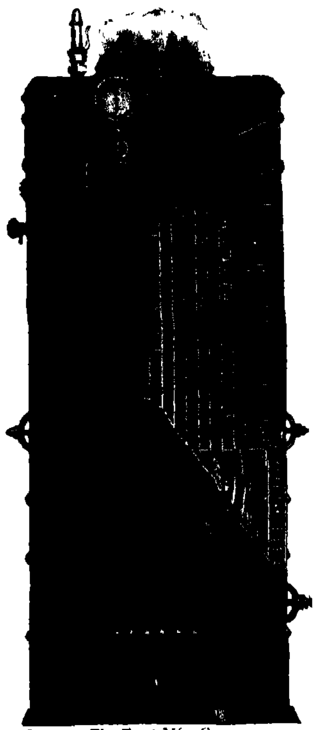
VICTORIES OF ENGINEERS AND CHEMISTS

AS civilization advances, population presses on the means of subsistence, and a sense of the folly and sinfulness of waste is awakened. Not only is the fact of the waste itself mournful and reprehensible, but the disposal of the wasted products themselves is costly and often offensive.

Waste may be very broadly grouped under two heads. One is that of power agencies, the other the by-products thrown out in the preparation of primary products. The waste gases from iron-furnaces, the coke from gas-retorts, the refuse of cities, and the inferior fuels are familiar examples of the first. Illustrations of the second are the by-products and wastes of chemical and other industries which are not sources of power.

Heat is the primal agent of power—heat derived from coal and held in the grip of steam; heat stored up in gas derived from coal, and oil and waste fuel; and that surplus heat much of which passes the wit of man to utilize. Although the amount of coal that is now used to yield a horse-power is only from one-sixth to one-eighth of the quantity employed a hundred years ago, the waste is still appalling.

Let us consider more in detail the question as to the power wasted when the heat energy of steam is made to do useful, mechanical work. The first steam boilers were simply hollow shells partly filled with water, so that an application of heat to the exterior of the shell would heat and eventually vaporize the water. These boilers were, of course, very inefficient and wasteful and they were later improved by introducing a large number of tubes into the water space and causing the hot gases to pass through these tubes. These were called "fire-tube boilers" and gave much



Courtesy The Frost Mfg. Co

VERTICAL FIRE-TUBE BOILER

The waste elimination is decreased and the efficiency of the boiler made greater by increasing the heating surface through the use of fire-tubes which divide the water space as shown in cross section

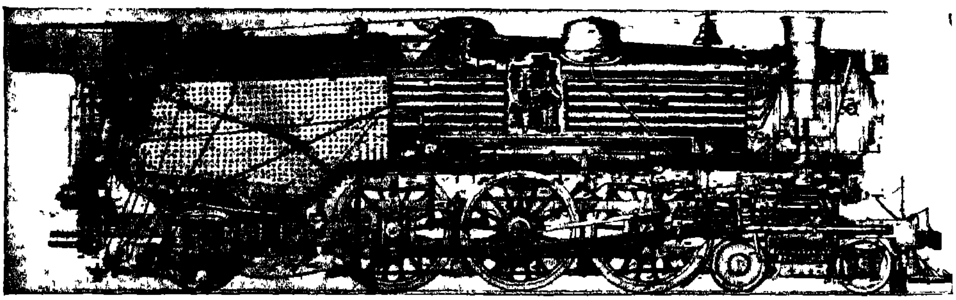
better results. This type is well illustrated by the accompanying sectional view of a vertical fire-tube boiler. Other improvements came later and these will be taken up in a subsequent chapter.

In any type of boiler about 60 to 75 per cent of the heat supplied by the coal goes into heating the water and making steam; of the remainder perhaps 10 to 15 per cent is lost through radiation, leaving from 10 to 25 per cent to pass away up the chimney. Now some of this heat on its way toward the chimney may be used for heating the feed water before it is pumped into the boiler, by placing a number of coils of pipe, through which the water must pass, directly in the path of the hot gases.

Such a coil as this is called an "economizer." It is one form of feed water heater, and by its use a saving in coal of as much as from 8 to 10 per cent may frequently be made.

The economy of engines has been somewhat increased by increasing the number of cylinders, as in the compound, triple and quadruple expansion engines; by increasing the steam pressure and by lowering the back pressure against which the engine exhausts. By the use of a condenser, this back pressure may, in some cases, be reduced to an amount not far from a perfect vacuum. The use of a condenser of course, allows the condensed steam to be used again in the boiler.

Many thousands of dollars are thrown into the air every year in the shape of steam which, having done its work in engines, is sent to waste, instead of being utilized in the ways just mentioned. This waste occurs largely in factories, and in electric-power stations. Yet in the same factories a separate heating apparatus for the workshops will often be found to have been installed, quite regardless of the fact that the steam thus wasted would warm the buildings efficiently, or heat water, and yet would cost absolutely nothing.



© Angus Sinclair Co Courtesy *Railway & Locomotive Engineering*

THE EXHAUSTIVE TRANSFERENCE OF HEAT FROM COAL TO WATER IN THE LOCOMOTIVE

The hot gases rising from the furnace of the boiler, at the right pass toward the left through the tubes or flues in the boiler While in these tubes heat is transferred from the hot gases to the water surrounding In the space above the water steam is formed and from here it passes through the connecting pipe to the engine

If the pumps and blowers in the boiler-room are steam driven, the exhaust steam from these engines may be used to still further heat the feed water. In many cases, the steam from auxiliaries in the engine room and sometimes from the main engine itself, is used for this same purpose. Feed water heaters using exhaust steam will usually save about as much coal as an economizer.

In the steam engine the waste is even worse, for, of the heat supplied to the best designed and most economical engines, not much over 20 per cent goes into useful work. Not all of the heat which passes out in the exhaust steam is lost, however. It may be used for heating in various ways: for feed water, or for some commercial process or, in cold weather, for heating the building.

The economical system of the wholesale heating of houses

In some parts of our country, where the winters are cold, there are two hundred central stations which supply only heat to warm public buildings, factories, and private houses. In general, however, each individual firm or institution lays down its own plant at enormous aggregate cost, while thousands of tons of exhaust steam which might be profitably utilized are discharged into the atmosphere.

SMOKELESS RAILROAD OPERATION

THIS IS THE WAY THE 28TH STREET YARDS OF THE PENN. R. R. AND IMMEDIATE NEIGHBORHOOD USED TO LOOK

Courtesy Bureau of Smoke Regulation of the City of Pittsburgh

RAILWAY YARDS AT EAST PITTSBURGH, BEFORE AND AFTER ABATEMENT OF THE SMOKE NUISANCE

All the millions of tons of steel now made in the world in the open-hearth furnaces are melted to a large extent by the waste heat in the furnaces themselves. The method is almost ridiculously simple. It just consists in the conduction of the waste gases from the furnace, as they go on their way to the chimney, through a wall of open or "chequered" brickwork. These gases make the brickwork extremely hot, rendering up to it nearly all their heat before they are discharged into the chimney. Then at that stage the incoming cold gas and air required for combustion in the furnace are brought into it through the hot brickwork, becoming, of course, highly heated on their way. The obvious result is an immense saving in fuel.

The early use abroad of directly driven gas engines using gas waste

About a dozen years ago Belgian and German engineers showed the way to a better system of using waste gases — to drive big gas engines direct instead of to raise steam in boilers. European engineers, on account of a smaller supply of natural resources to draw from, have been quicker to adopt and perfect this practice than have we in this country. The idea started in England where, in 1893, a plant was fitted out. The Cockerill Company, of Seraing, near Liége, in Belgium, built the first very big engine, one of 600 horse-power, which excited great interest at the Paris Exhibition in 1900. During the years which have followed, gas engines have been built in increasing sizes, until now they frequently develop 6000 horse-power.

An ordinary blast-furnace will not only supply enough waste heat to drive its own powerful blowing-engines, but will yield a surplus of about 800 horse-power per ton of pig-iron produced per hour, and a modern blast-furnace will produce from 400 to 800 tons of pig-iron per day. There would, therefore, in an ordinary, modern blast-furnace plant be developed about 50,000 horse-power over and above that necessary for its own power uses. The United States Steel Corporation saves over a million tons of coal per annum by the adoption of this method.

Germany has always been one of the greatest producers of pig-iron. She has also been one of the foremost countries to successfully develop power from blast-furnace gas. Although since the war France has forged ahead in blast-furnace work, an enormous amount of power is being developed from the blast-furnace waste in both countries.

The varied uses to which furnace slag is now very profitably devoted

Slags, which are waste from the blast-furnaces, have different uses, as they differ from one another in chemical structure. In this country and Germany certain slags are used largely for Portland cement.

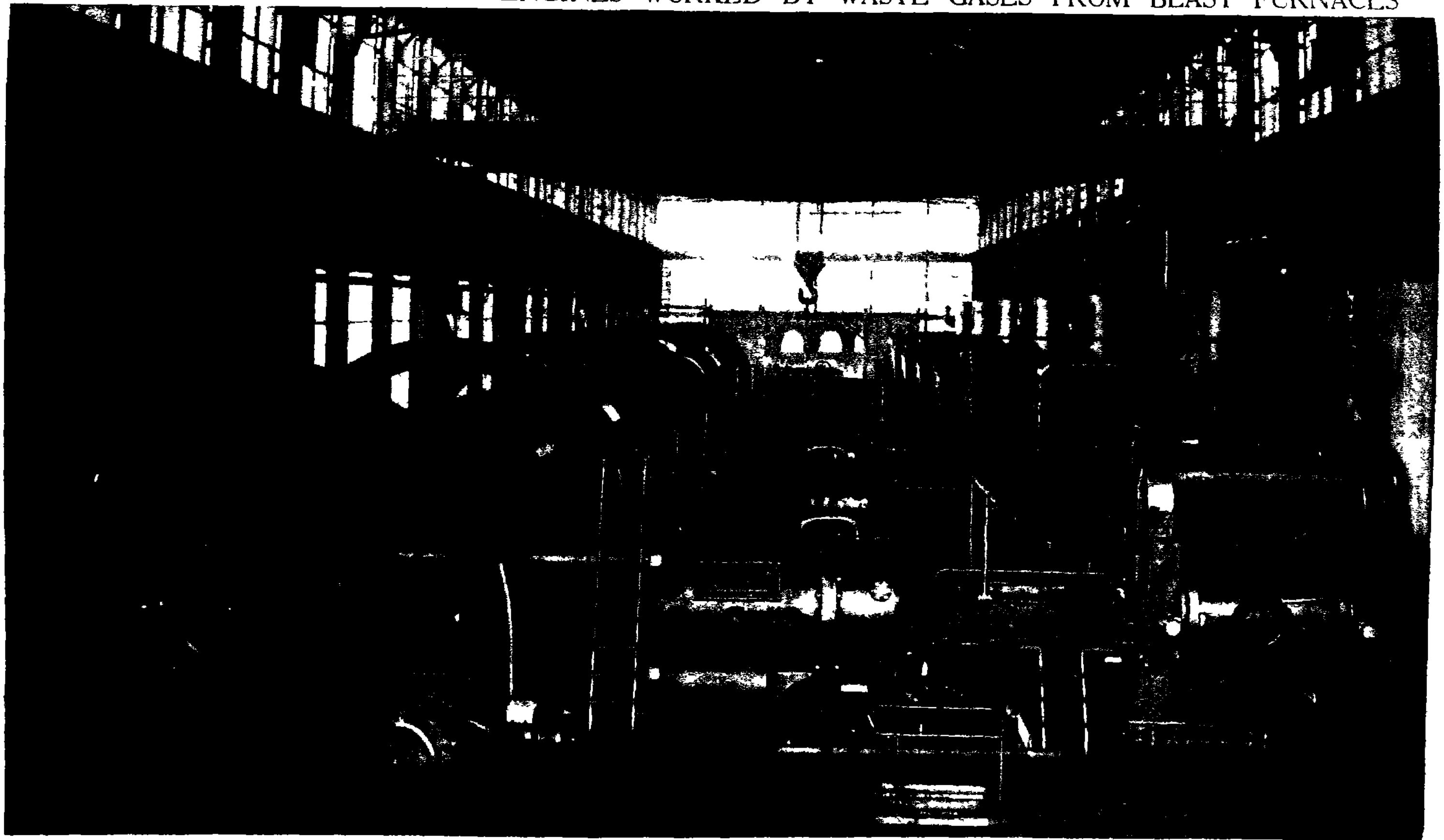
Many require the addition of only 10 to 20 per cent of the real Portland cement and a small quantity of gypsum to make a cement as good as, and, for use in sea-water, better than those that are made wholly of Portland cement.

Slag made from the basic Bessemer process is now always ground in mills and used as fertilizer. It owes its value to its phosphorus, which is fluxed off from the iron ore. The higher the phosphorus, the more valuable is the slag. And it so happens that the presence of phosphorus even in small quantities makes bad iron. So that in removing practically all the phosphorus from the iron in the converter, the steel maker increases the market value of the slag.

Another of the important utilities of slag is in the preparation of non-conducting coverings to prevent radiation of heat from steam-pipes and cold storage chambers, etc. A jet of steam is directed on the stream of molten slag as it flows from the furnace. Many tiny particles or "shots" of slag are thus blown out from the mass, which draw fine, glass-like threads after them. These are sucked through a tube and deposited on a sieve. The wool thus produced is one of the very best obstacles to the transmission of heat.

It is as fire-resisting as asbestos. It will not become converted into a solid mass by vibration. Moisture does not affect it, as it does wool and hair and some other substances used for "lagging."

SEVEN 600-HORSE-POWER GAS ENGINES WORKED BY WASTE GASES FROM BLAST FURNACES



In Germany it is very common to use waste gases from blast furnaces for running gas engines, and the practice is not at all uncommon in our own country.

The challengers to the reign of coal as a power fuel

Slag is used with lime for making bricks. They are more expensive than common bricks, but are much harder and better able to resist crushing; also, they do not absorb moisture, and thus houses built of them can never be damp.

The present age is marked by the immense rivalry of gas with coal as a power-fuel. Either in the form of gas used directly, or vaporized from oil at the engine, it has invaded spheres where the steam-engine had no rival a few years ago. Vessels now cross the Atlantic with engines driven by oil fuel, the greatest and swiftest liners among them. Many have been converted into oil burners and many others are now building both in this country and abroad.

Three causes have been and are increasingly contributory to this result — the enhanced cost of high-class fuel, the employment of electricity for power-driving, and the enormous potentialities of the internal-combustion gas or oil engine. The cost of fuel of high heating — "calorific" — power concentrated attention on the enormous reserves of inferior fuels, in the heaps of cinders and waste rubbish in the immediate vicinity of collieries, which were accumulated in more halcyon days.

The transformation of cheap fuels into electric current for light and power

Electric developments have rendered it possible to transmit power over considerable distances, so that very large units of power can be produced in a very economical manner from cheap, low-grade fuels, and the power thus produced distributed over a large area to factories, street railways and the like. The cost to these will not be nearly so high as it was when they generated their power in a smaller station, using expensive coal.

In fact, it is cheaper to sell waste heat or power to a central undertaking, and purchase it back in the convenient form of electric current, than to maintain a private electrical power-house driven by a steam or gas engine.

Much of the producer gas used in internal combustion engines is obtained from inferior fuel that was formerly wasted. For example, the fuel from which Mond gas (a gas, the process for producing which originated in England) is made is of this character. It is common bituminous slack. From 120,000 to 150,000 cubic feet of gas are got from a ton of fuel, and, besides this, a large amount of sulphate of ammonia is obtained as a by-product.

Over a million horse-power of big waste gas engines are now in use in the world. Of these, the United States, France and Germany employ a very large proportion.

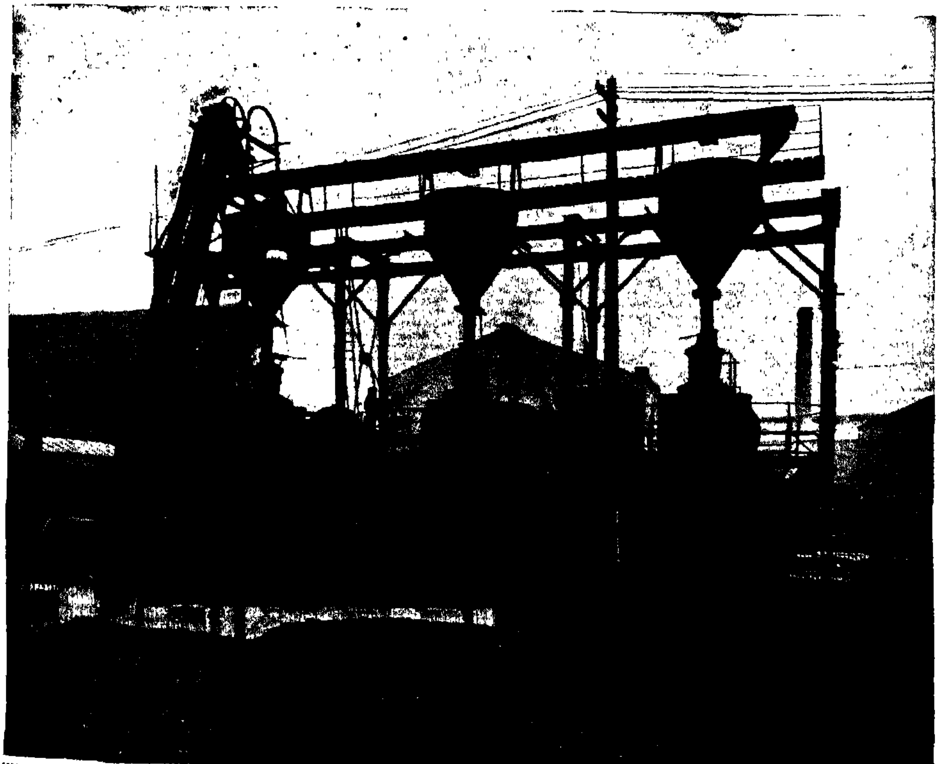
Will the time come when nations can be supplied with power from one center?

In some districts in Germany surplus portions of the waste gases from furnace coke-ovens are sold to the towns for illuminating purposes. In Westphalia alone, it was estimated before the war that gas to the value of $10,000,000 yearly was being lost. Now a good many towns in this and other districts are taking this waste gas for lighting, and are closing their own gas-works. In one case the supply contracted for by the municipality had to be brought through thirty miles of pipes — a long distance for gas. The collieries in connection with Krupp's works at Essen are supplying many towns with waste gases.

The movement now in progress is not going to end with the supply of actual gas. The other supply, that of electricity, will go hand in hand with it. In time the great coal and iron districts of Westphalia and Silesia will supply both gas and electricity to the greater part of Germany. Waste furnace gases and coke-oven gases, and small and inferior coal, at present unmarketable, will be the materials by which the present inefficient and costly supplies will be driven out and methods revolutionized.

It is a noteworthy fact that where blast-furnace gas is used as a source of power, the quantity available is so large that installations to develop power from that source must be on a very large scale. Such plants provide an inexpensive as well as efficient method of furnishing power.

VAST POWER FROM OBSTRUCTIVE REFUSE



The upper photograph shows a Mond gas plant used at a colliery in England for making gas for driving gas engines. All the power needed at the colliery is produced from such refuse as coke cinders. Valuable sulphate of ammonia is also extracted in the gas-making process. The lower picture shows a 6000-horse-power Mond gas plant that uses up each week 60 tons of the slack seen in the foreground.

One of the most striking facts in connection with many gas-producer plants is not only the gain of two, or two and a half, times over steam-power plants, but in the by-product recovery-plant attached thereto. It is literally true that in such cases firms get their gas for nothing, because the by-products pay the expense.

Gas is both a primary and a by-product. There are two kinds of coke — that made for use in blast-furnaces, and that from which illuminating gas has been made. In the first the coke is the primary product, and gas is the waste; in the second, the gas is the primary product, and the coke is the waste. The two cokes are vastly different in composition: the first is hard, lustrous and is nearly pure carbon; the second is soft, dull and impure.

The enormous value of the by-products, once entirely wasted, from hard coke

Formerly there were no other by-products from the hard coke except the gases. Now most ovens are constructed to recover by-products similar to those which are obtained from cities' gas-retorts. These are chiefly tar and ammonia. From the distillation of the tar are produced naphtha, benzol (used as a fuel in internal combustion engines), color oils, aniline dyes, pitch and creosote oils from which come naphthalene and carbolic acid. Picric acid, the main ingredient in the latest high explosives like lyddite, melinite, maximite, etc., is made from carbolic acid. Beside the value of the ammonia as a fertilizer and in refrigeration, it is used in the manufacture of munitions and soda is made by an ammonia process. In 1920 the coke production in the United States was 51,345,043 tons valued at $494,246,254. The value of the by-products of this coke was $93,692,764, a utilization of waste well worth while.

It is a startling fact that enough heat may be generated by the burning of a town's refuse to furnish power for street lighting. Many places now treat their refuse as a valuable by-product. It is all burned in destructor furnaces, built generally with the brick-work regenerators of the steel furnaces.

Furthermore, from the burning of the refuse itself some by-products result, although the primary product is hot gases, which are consumed in boilers to raise steam to drive engines, that in turn generate electricity from dynamos. Actually it costs less to burn the refuse thus and employ the products than it does to dump the rubbish in heaps on valuable land. For every day it accumulates at the rate of from fifteen hundred to two thousand pounds for each one thousand of the population.

The noisome refuse of cities used to light them and drive street cars

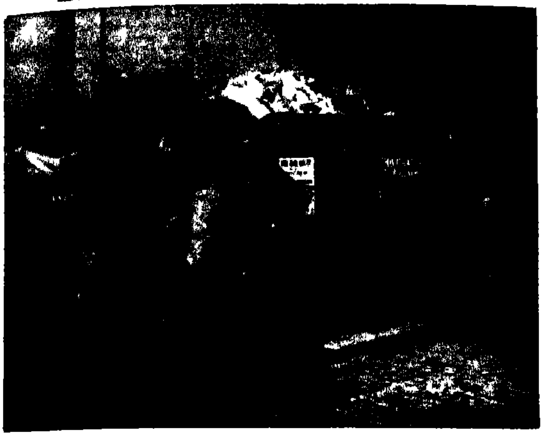
Yet the refuse is of very low value as fuel, being only from one-fifth to one-fifteenth that of coal, so low, in fact, that it can only be burned in furnaces specially constructed for the purpose. Yet steam is produced at a pressure of 200 pounds per square inch from this waste rubbish.

The furnaces are of various types, but in general they comprise separate combustion cells, the employment of forced draught, and the use of hot air treated in regenerators. Cities are lighted and street cars driven by the burning of the evil-smelling, disease-laden contents of the dust-bins and rubbish heaps.

The wealth that escapes visibly and invisibly up our chimneys

The waste in fuel due to imperfect methods of combustion is somewhat less than one-third. That is, of the heat which is developed by the burning of one pound of fuel, about 70 per cent does useful work. Usually about two-thirds of this wasted heat passes off in the chimney gases. These gases may or may not be visible as smoke. The visibility of smoke, however, is not necessarily a measure of waste heat. The heat loss due to visible smoke is usually about one per cent. A very small percentage of smoke is unburned carbon while a large part is made up of unburned gases composed of different combinations of carbon and hydrogen. Smoke also contains some ash and soot. These with whatever carbon is present will, if improper methods of combustion exist, be deposited over the surrounding country as a nuisance.

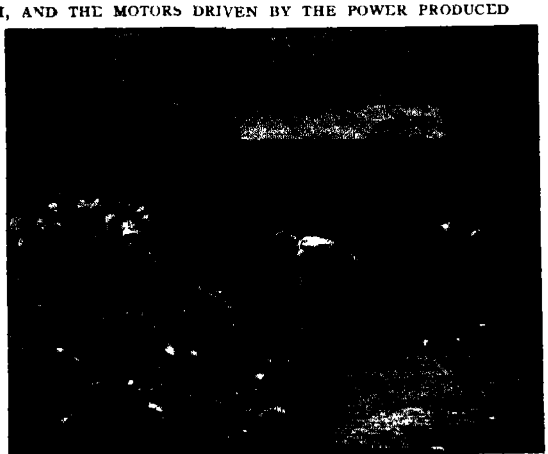
BRINGING POWER FROM A RUBBISH HEAP




HOUSE REFUSE BROUGHT TO A DUST DESTRUCTOR AND LOADED ON AN ELECTRICALLY DRIVEN BIN


THE FURNACE THAT BURNS THE RUBBISH, AND THE MOTORS DRIVEN BY THE POWER PRODUCED

THE HUGE SWITCHBOARD THAT CONTROLS THE ELECTRICITY PRODUCED BY RUBBISH



STORING THE ROUGH AND GRADED CLINKER FROM THE FURNACES FOR USE IN BUILDING AND ROADMAKING

In recent years, this smoke problem has assumed such proportions in the large cities that rigid laws, strictly enforced, are now in use in all parts of our country regulating the quantity and quality of smoke. The problem can best be met by improvements in furnaces and in methods of stoking. Much has already been done in this line and these efforts to avoid breaking the laws have, at the same time, resulted in improving the efficiency of the plants and in reducing waste.

What the engineer has accomplished in utilizing potential energy

The task of the engineer is to harness and direct the forces of nature into channels for the service of mankind. He abhors waste, yet he is ever faced with the fact of immense wastes of energy in every engine and machine he builds. The greatest forces in the world — the waterfalls, the tides, the wind, the sun himself, the very springs of potential energy — are lavished in vain in the sphere of human industry, while the muscles of poor humanity are put to incessant overstrain, and the soul of the toiler is brutalized by the ceaseless drudgery of his tasks. The engineer has done much to alter this, but almost always by the help of one agent — the sun's energy, which was stored up millions of years ago in coal.

The harnessing of falling water to relieve humanity's tired muscles

In recent times the harnessing of the power of falling water has become so familiar that it arouses little wonder. The old water-wheels, clumsy and inefficient, have given place to the smaller but more powerful turbines. These are adaptable for falls of from four to a thousand feet. At Niagara, at the Victoria Falls, in California, Switzerland, South Germany, France, Scandinavia, Italy, the volume of water-power increases and the steam-engine disappears. Yet but for the fact that the electric dynamo has been developed along with the turbine, changing the rotation of the latter into electricity, not one thousandth part of the water-power that is now utilized could have been developed.

In the early days such power was transmitted from the turbines for short distances only. Now electricity is carried hundreds of miles in some installations, driving street cars and machinery and mines, and illuminating teeming cities far removed from the roar of the cataracts. Every year the amount of water-power laid under contribution increases by leaps and bounds. Yet what is taken is ridiculously small by comparison with what remains unutilized.

Practically all the potential power stored in the wind is wasted daily. Only a very infinitesimal proportion is utilized. Yet lavish nature makes no charge for wind A windmill is one of the simplest pieces of mechanism made by engineers. It is so simple in construction that breakdowns are rare. There is no trouble with boilers, or furnaces, or fuel storage. And if it be objected that wind-power is intermittent, so, too, is much of the work for which engines are used. A windmill can be relied on to run, say, eight hours out of the twenty-four, and electric storage cells will provide supplies for the other hours.

How the windmill may come to our aid when the coal problem becomes acute

The principal work done by windmills is pumping, chaff-cutting, grinding and driving small machinery for farm work. Very often country houses are lighted by electricity through the help of storage cells. A modern windmill, not the antiquated structure beloved of artists, is an excellently made piece of mechanism, with ball bearings, and having self-acting mechanism by means of which the vanes or sails themselves turn to meet the wind as its direction changes. Assuming an average velocity of wind at fifteen miles an hour, a mill with sails twenty-two feet in diameter at thirty-six revolutions per minute will give out one horse-power. Many mills are larger than this, ranging up to forty feet in diameter. At some not very distant day, when the coal problem becomes acute, the long-neglected windmills, dating from the twelfth century, dispossessed of their ancient favor by the fussy steam-engines, will come into their own again.

In recent years wind-power has been sought afresh, particularly for pumping water Here we have two examples of modern windmills, adaptable and graceful, quite unlike the lumbering stability of old mills

In all industrial lands inventors have longed to utilize the vast amount of power lavishly poured out and wasted daily by the beneficent heat of the sun shining on the waste places of the earth. Many attempts have been made to harness these rays for useful work, and some day, when the coal famine is upon our descendants, the idea of sun-power may become matured, and the problem of smoke consumption will then cease to worry. Sun-power motors, to be commercially successful, must, for the present at least, cost less to maintain than those which require coal or other fuel to drive them. They can only, therefore, be employed in countries where coal is costly, and of course, too, under cloudless skies. These two conditions exist in tropical lands, but not in the United States, nor in any of the northern countries.

Immense sources of wealth lie in the by-products and wastes of many industries outside the power agencies we have been considering. Many people wonder what becomes of all the various scrap metals. The government Geological Survey issues each year statements showing the amount of production of different metals and this includes that which is recovered from waste as scrap sweepings, etc. The amount of this recovered scrap is amazing and represents an annual value of several millions.

The wand of the Arabian Nights' magician now wielded by the chemist

The chemist is a magician more potent than any who charmed our childhood in the "Arabian Nights." Locked up in the coals are hundreds of lovely dyes which he extracts by distillation and solution. These are all by-products, and until Sir William Henry Perkin, in 1856, discovered their value, were absolute wastes. Previously only tar was recovered, a crude substance having such limited utilities that it was of slight value by comparison with its separate constituents, and was, in fact, often burned to get rid of it. Actually this black and sticky tar is a compound of about two hundred different substances, occurring in larger or smaller quantities, and of less or greater value.

The marvelous story of the coal-tar dyes is one of the romances of industry. Fifty years ago they were unknown. Previously all the dyes used had been derived from the animal or vegetable kingdom. They were mostly unstable, some were procured with difficulty. But they had no rival until Perkin obtained the first aniline mauve dye for silk. This was followed by the discovery of aniline magenta. Until 1860 these were the only dyes made from coal-tar, and magenta then brought $150 per pound. Afterwards aniline blue was also obtained, and later progress was rapid.

Now there are some hundreds of dyes derived from coal-tar, every one being a definite chemical substance, though known only to the trade and to the public under popular, unscientific names.

The chemical industry at present is occupying one of the foremost places in the eyes of the world. Chemicals and what are they? Well, alkalies and acids, sulphates and chlorides, and chiefly carbonate of soda and sulphuric acid. Chemicals lie at the basis of cheap soda, cheap soap, bleaching-powder, dyes, oils, calico and woolen industries, pottery, gold extraction, baking powders, washing blue, paper making, ordinary paints, photography, glass-making, explosives, enamel — and hundreds of other industries. Some of these are primary products, many are by-products, once wastes but now of high value.

There are cases in which a more expensive and roundabout process is chosen rather than a less costly one, by which to manufacture a primary product solely in order to be able to sell by-products. Thus the Solvay ammonia process for the preparation of the carbonates of soda is much cheaper and simpler than the Le Blanc process. Yet the latter is often adopted in order to obtain bleaching-powder and chlorates as by-products, and, in a lesser degree, the sulphur in the residue. Hydrochloric acid gas was a by-product in the Le Blanc process which, until a way was found to condense it in water, was a very grave public nuisance. By means of Gossage's condensing towers this waste is now practically all turned into wealth.

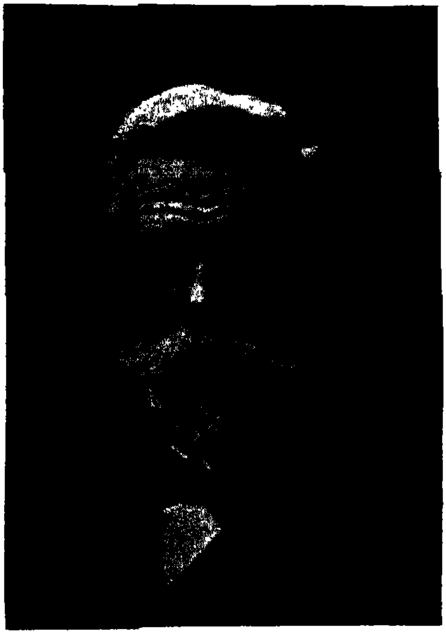
Undoubtedly the most valuable single product, after iron, is soda. It has taken the place of the potash once extracted from wood ashes and seaweed. Le Blanc (1742–1806), competing for a prize of £[illegible]00 offered by the French Academy of Sciences for a method of turning slat, which is plentiful, into soda, invented the process known by his name. He treated salt with sulphuric acid, producing sulphate of soda — "salt cake" — and hydrochloric acid gas. To the salt-cake he added charcoal and chalk, and by slowly heating the mass produced carbonate of soda, leaving a heavy, gray, muddy sediment, "alkali waste," in which later investigators have found a source of great wealth. No other process was employed until 1872, when Ernest Solvay, the great Belgian manufacturing chemist, invented the one known by his name, in which less than half the fuel required for the other is used, and no solid residue is left.

The waste products of the Le Blanc process were the hydrochloric acid gas evolved by the contact of the sulphuric acid with the salt, and the gray, muddy sediment. The first was nothing but a nuisance until Gossage invented a method of its recovery by its condensation and absorption in a descending stream of water in a tower. This acid is composed of hydrogen and chlorine. Now, chlorine had been known since the days of Watt as a powerful bleaching agent, accomplishing in a few hours what had required exposure to sunlight for a whole summer to effect. Chlorine was utilized in the form of chloride of lime, or bleaching-powder. But the manufacture involved the use of manganese, all of which was wasted, along with two-thirds of the chlorine. Later, the manganese was replaced by a method in which hydrochloric acid gas was passed over heated copper salts, with the evolution and recovery of all the chlorine. This left only the foul-smelling gray residue to be dealt with. The objectionable element of this was sulphur. Finally, by the Chance-Claus system, the sulphur is recovered in kilns by means of air and the waste gases from lime-kilns, so that now the cycle is complete without waste.

The great part played in modern industry by sulphur

When the Solvay soda-ammonia process was introduced, the Le Blanc industry would have been killed but that the recovery of the wastes, worth more than the primary product, saved it from destruction.

One cannot easily get away from the alkalies and their by-products. Take sulphur, and sulphuric acid, or "vitriol." Sulphur is an element the demand for which still increases. It is used in the manufacture of gunpowder, of vulcanized



ERNEST SOLVAY

rubber, in bleaching silk and woolen goods, in washing-blue, in paper-making, etc. Hundreds of thousands of tons of sulphur are used annually in the wood-pulp paper industry alone. Without an abundant supply of sulphur the manufacture of alkali by the Le Blanc process is impossible. But outside of this it has a hundred applications, many of which lie in the extraction of wealth from waste. Take bones, for example, which are converted into valuable fertilizers by crushing and subjecting them to the action of sulphuric acid, yielding phosphoric acid and super-phosphates.

Now, sulphur is a by-product in the Le Blanc process. But it is a primary product in the roasting of pyrites, the chief supply of which comes from Spain. Arsenic, copper, iron and minute quantities of silver and gold are also by-products, but were for many years ugly heaps of waste. After the sulphur was expelled from the pyrites by roasting, the residue was waste. The quantity of copper present was very small. But at length the cinders were ground to powder, mixed with salt and roasted, yielding copper chloride, which was rendered soluble in water along with the silver and gold, which were afterwards recovered, leaving a pure iron oxide that is melted in the blast-furnaces. The result now is that the quantity of copper in the pyrites, and not the sulphur, regulates the price; and, as copper is high, pyrites have risen in sympathy.

Soda and potash as up-to-date gatherers of gold

Sulphuric acid is the most important chemical employed in industries. It is made directly from sulphur, or from iron pyrites. Yet much more sulphuric acid is wasted by the consumption of coal in this country than is used for manufacturing purposes. Each ton gives off about 68 pounds of sulphuric acid, to the great damage of public buildings and the contamination of the atmosphere.

Without soda, or its first cousin, potash, the gold industry in the Transvaal could not have attained its present vast proportions. Gold is extracted from its ores, after crushing the rock, by taking advantage of its affinity for cyanide of soda, or potassium. Cyanide is a compound of soda with prussic acid. Chlorine, a by-product, suffocating as a gas, is yet one of the most valuable disinfectants known. Dissolved in water it is used for many purposes, for which neither carbolic acid nor mercuric chloride would be safe or suitable.

The story of the invention of the plush loom by Samuel Cunliffe Lister, afterwards 1st Baron Masham (1815–1906), is a most peculiarly interesting one of the utilization of absolute waste.

The plush-making romance that grew into Manningham mills

The stuff utilized was silk waste from India, thrown out in the manufacture, and consisting of pierced cocoons, dead worms, mulberry leaves and dirt. Lister bought a pile of it for a cent a pound, and spent twenty years in perfecting a process and a machine by which this uninviting rubbish was dressed and woven into "pile cloths" or "plush goods," as silk velvets, imitation sealskins, velvet ribbons, etc. He sank many thousands of dollars in these efforts, but at last the corner was turned, and before long 5000 persons were employed in the new industry at his mills and the profits ran to a million a year.

Large wastes occur in manufacturing cities and towns located on the banks of streams, in the form of trade effluents. Some of the rivers, particularly the smaller ones, are little better than open sewers of blue-black hues, embroidered with patterns in oils and grease, the despair of municipalities and sanitary authorities. A problem similar in character, but of universal interest, is that of the disposal of city sewage. In each the effluents are rich in elements which have industrial value, but methods of separation and questions of cost often set up obstacles to their use.

The difficulties lie in the very varied character of the wastes, and in the cost of the plants required for their recovery. As, too, in city sewage, one great obstacle lies in the immense amount of liquid present in which substances are held in solution. Solids would not offer a fraction of the difficulties in their utilization. In city sewage the older method of sewage farming is being superseded by the bacterial system, with septic tanks and filter beds. The work of purification is divided between the aerobic and the anaerobic bacteria. The latter in the septic tank disintegrate and liquefy solid particles, and ammonia is formed. Afterwards, by the aerobic bacteria in the filters, ammonia, carbonic acid and nitrates are produced, leaving a clear, innocuous effluent, while the solid particles have a varying value as fertilizer.

AMERICA'S NATURAL ENDOWMENT

The Material Environment in Which the American People Live and Work

WEALTH: COLLABORATION OF NATURE AND MAN

IT is but a commonplace to remark that the two essential factors in any country's material progress are, first, the character of its people and, second, the extent of its natural resources. Both human and natural qualities must be estimated in any appraisal of a nation's wealth. For only when the gifts of nature are bountiful and are intelligently utilized by man can industry function at its maximum.

Not infrequently does it happen, however, in countries upon which nature has frowned, that man, by the exercise of his own industry and talents, achieves more than in countries where nature has more beneficently bestowed its products. The presence of rich natural resources alone was not sufficient to render industrially efficient the sport-occupied American Indian nor the ease-loving tribes of warmer regions. For nature reacts upon man. Where the gifts of nature are superabundant, and may be called forth with little difficulty, man may not be impelled to exercise to the full his own innate resources; a bountiful nature may, as but too commonly in the tropics, only render man slothful.

Nevertheless, it is still true that where nature has been niggardly no people can achieve other than a mediocre industrial development. For man can mine only where there are minerals, build houses of wood only where there is timber, fish only where there is water. A bold, vigorous race like the Scandinavian has not been able to achieve great industrial success in a barren, inhospitable country such as Iceland; the semi-arid districts of western United States can never become the seat of a dense population. "No man by taking thought can add a cubit to his stature"; nor can he make good any great deficiency in the natural resources of his country.

Continental United States, not including Alaska, contains 3,026,789 square miles of territory, an area only slightly less than that of Europe, with its land surface of 3,700,000 square miles. Geographically it is most advantageously situated. Practically all of its area lies in the warmer half of the temperate zone. Its southern extremities, Texas and Florida, do not quite touch the tropics, but are much nearer the equator than is any point of Europe. The latitude of New Orleans is the same as that of Cairo, Egypt. In the north, the forty-ninth parallel, the northernmost boundary line, is the latitude of Paris. But, removed from the warming Gulf Stream, only a narrow belt of the American territory north of the United States and southern Canada is suited for an intense cultivation or a dense population. Only a small portion of the United States, however, lies north of the corn belt; and other cereals, such as wheat, oats, rye, may be grown throughout four-fifths of its area. For the grazing of cattle and sheep, districts in all parts of the country are suitable. It is remarkably well supplied with minerals, particularly in those essentials of industry, coal and iron. Lying in the temperate portion of the continent, the United States is much more richly endowed than the slightly larger territory of Canada, full of magnificent promise as that region is.

The United States has one mile of coast for each 165 of area, to Europe's 224

The eastern and western boundaries, the Pacific and the Atlantic, provide the country with an enormous coast line, altogether 18,000 miles in length. Europe, the most favored of the continents in this respect, has 19,500 miles of sea-coast, but 3000 of these are within the Arctic Circle and not, therefore, available for commerce. Deducting the arctic frontier, Europe has only one mile of coast for each 224 miles of land area, whereas the United States possesses one mile of coast for each 165 miles of area. And not only is the United States thus favored with many magnificent harbors, but it is also well provided with a system of long and navigable rivers. The Mississippi River system alone drains over 1,000,000 square miles of territory.

A resident of western Europe, asked to describe our climate, would likely utter the single compound word, "tropical-arctic." In summer there is intense heat, in winter extreme cold. Particularly in the states of the Mississippi Valley is the temperature scorching in summer, but it is not at all uncommon in winter to find the thermometer at twenty degrees below zero in such cities as Minneapolis, Omaha, and Chicago. Practically all the Southern States are liable to cold waves in winter, the only states with uniformly mild winters being those of the Gulf and Pacific coasts.

The wide range of our climate a great aid to the diversification of crops

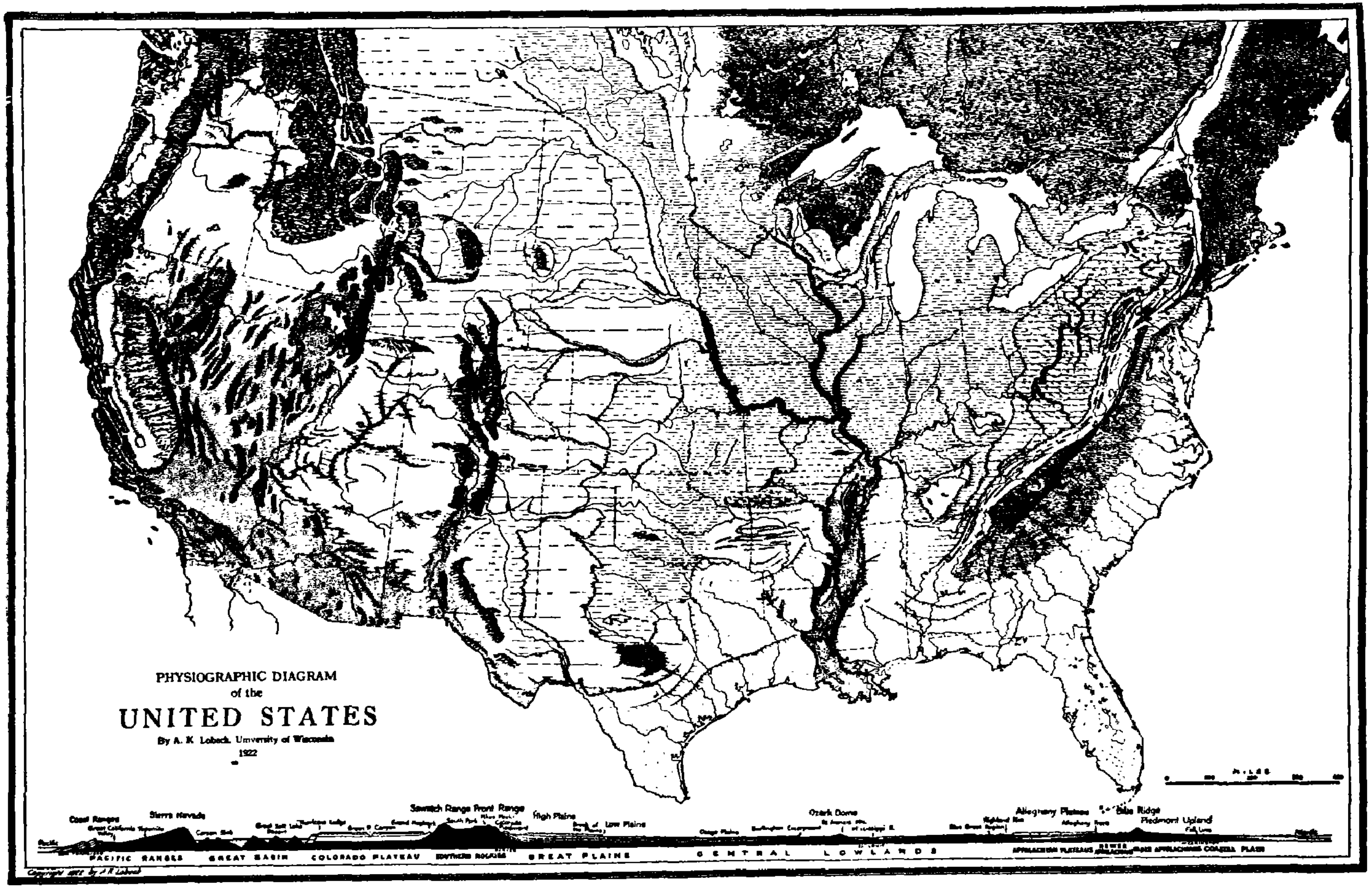
But varied as is the climate, the months of summer heat are sufficiently long and intense to render the country the world's greatest corn-producing area. And the wide range of climate has aided greatly in the diversification of the crops. The danger of a general crop failure is lessened by the probability that deficiencies in one part of the country will be offset by bountiful yields in another. Only countries possessing both a broad expanse of territory as well as a great variety of climate may hope to become self-sustaining.

Regions with an average yearly rainfall of less than eighteen inches are not suited for the normal processes of agriculture. In the more arid districts crop growing is usually subordinated to grazing. The average annual rainfall of the United States is about thirty inches; east of the hundredth meridian, which passes through the Dakotas, Nebraska, Kansas, Oklahoma, and Texas, the average is much higher than this. West of the hundredth meridian, as far as the tablelands of the Rockies, the rainfall decreases; this intervening area is the "dry lands" region, where cultivation must be suspended because of the prevalence of droughts and the irregularity of the rainfall. In the sub-arid zone lies about one-third of the territory of the country. By the processes of irrigation or dry farming, however, much of this semi-desert territory is being reclaimed for cultivation, and much more of it will unquestionably be reclaimed in the future.

The length of the growing season no less important than amount of rainfall

Scarcely less important than the amount of rainfall is the length of the growing season. This is determined by the dates of the last killing frost in spring and of the first killing frost in the fall. The United States Department of Agriculture has made an elaborate investigation of this important subject. In this one respect the agricultural possibilities of the United States are in some measure limited as compared with those of the larger part of Europe, where the extremes of heat and cold are less, and where the growing season in general is longer. The dates at which killing frosts occur do not depend alone upon latitude. Altitude is nearly as important, and even in the case of comparatively small differences of elevation, the severity of the frost may be less on the hillsides, or even the hilltops, than on the valley bottoms by reason of the tendency of the coldest air to collect at the lowest levels.

The average growing season varies from three hundred and sixty-five days at Key West, Florida, to considerably less than


PHYSIOGRAPHIC DIAGRAM
of the
UNITED STATES
By A. K. Lobeck, University of Wisconsin
1922
Coast Ranges
Sierra Nevada
Sawatch Range Front Range
High Plains
Low Plains
Ozark Dome
Allegheny Plateau
Blue Ridge
Piedmont Upland
PACIFIC RANGES
GREAT BASIN
COLORADO PLATEAU
SOUTHERN ROCKIES
GREAT PLAINS
CENTRAL LOWLANDS
COASTAL PLAIN

ninety days in the extreme northern portions of the country and in some of the high plateau regions of the West. Where the growing season is less than ninety days, general agriculture is usually not profitable. Such regions may be more profitably devoted to forests. The longest safe growing season is found in the states bordering on the Gulf of Mexico, in southern Arizona, and in parts of California. The safe growing season in the eastern part of the United States varies from about two hundred and forty days along the Gulf of Mexico to one hundred days or less in Minnesota or the Dakotas, and ninety days or less in parts of the Appalachian Mountains and in the higher altitudes of northern New York and New England. In many of the more elevated regions of the West the safe growing season is less than ninety days.

The localization of our industries due to sectional physical characteristics

With its broad expanse of territory, broken up by two great mountain chains, its varied climate and rainfall, industrial United States must inevitably have developed a great diversification. To gain even a rough picture of the localization of industries in the United States necessitates a consideration of the peculiar physical characteristics of the different sections. For our purposes we may divide the country into the following sections, the North Atlantic, the Southern, the North Central, and the Western.

The North Atlantic section includes the New England States and New York, New Jersey, and Pennsylvania. In gross area it is only 5.6 per cent of that of the entire country. In this section, however, nearly 30 per cent of the American people obtain their livelihood. Such density of the population as this is made possible only by the great development of the manufacturing industries. If we glance at the recent census figures, we shall find that the value of its manufactured products amounts to nearly half of the total for the entire country. And in its shops and factories are employed half the workers engaged in the manufacture of goods.

Why 30% of the people earn their living in an area only 5.6% of the whole country

But what qualities make for the manufacturing supremacy of this section? Assuredly it is not its nearness to the sources of raw materials. For neither in minerals nor in soil fertility is this section comparatively rich. New England is an ancient mountain region worn down by long exposure to the elements; its lowlands are small and its climate harsh. In the Middle States the glaciers of the ice age stripped the uplands of their original soil and scattered a deep layer of glacial drift or rock waste over the entire country. Only a small part of New England where the glaciers passed is fit for the plow. The Middle States, possessing a milder climate and a more level surface, are better situated in this respect, but are still not to be compared in soil advantages to the Middle West and South.

The explanation of the manufacturing supremacy of this comparatively small region we find then to consist in, first, the abundance of its mechanical power; second, its excellent shipping facilities; and, lastly, the impetus of an early start.

In a previous chapter it has been pointed out that where mechanical power resides, there manufactures must go. Coal cannot be economically transported any great distance, and science has not yet discovered any means of conveying electrical power far from the site where it was generated, without undue loss. In both coal and water-power the North Atlantic region is well endowed. Many of the rivers are narrow and swift and descend rapidly from considerable elevations. The lakes, formed by glacial action, furnish natural reservoirs and thus insure a constant flow. Indeed New England makes a larger use of water-power than any other section, and in the Niagara section of western New York the water-power advantages are unexcelled.

In shipping facilities, also, nature has richly endowed this section. In the possession of numerous natural harbors the North Atlantic States possess great advantages over the South Atlantic.

South of the Hudson the coastal plain is broad, extending in some places more than 200 miles. For the most part approach to the shore is permitted only where buried river channels lie. South of New York City good harbors are therefore few. But north of the Hudson the coast is "drowned," and is exceedingly indented. These drowned valleys make the best of harbors. And so it is that this section possesses the country's greatest ports, as New York, Boston and Portland. Through New York alone half the foreign trade of the country is conducted, and of the others, Boston is surpassed by very few of our ports.

But even the best harbors in the world would be of little avail without ready access to the interior. In mountainous sections railroads seldom penetrate great distances, except along river valleys. But in this respect the North Atlantic is well cared for. The chief route to the West was from earliest days the Mohawk Gap. For more than a century this has been a dominant factor in the commerce of the continent. Used by the Indians, when it was known as the "Iroquois Trail," it later furnished the route of the Erie Canal. Along its course there developed a row of prosperous cities — Albany, Troy, Cohoes, Schenectady, Utica, Syracuse, Rochester and Buffalo. Through it there run six lines of rails, constituting a great highway to the West which crosses the Divide where the grades are least.

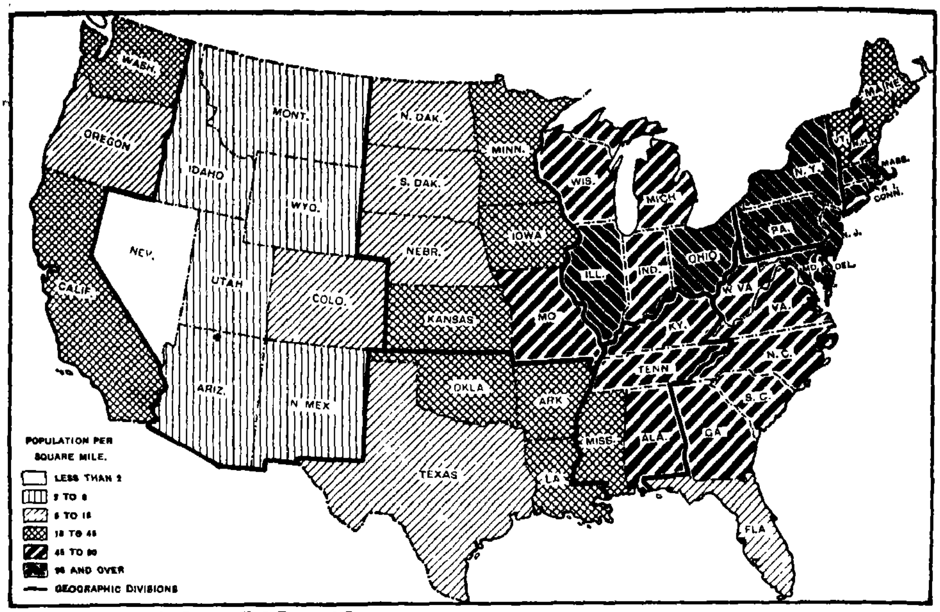
Ever since the building of the Erie Canal through the Mohawk Gap, New York's supremacy as the great marketplace of the continent has been unchallenged. These railway lines, together with the New York State Barge Canal, constitute, in reality, an extension of the Great Lakes route to the East. Chicago and Duluth, therefore, may be said to stand at the western end of the Mohawk route. Turning farther south, other gaps through the mountains, utilized in turn by Indian trails, canals, turnpikes and railways, connect the great ports of Philadelphia and Baltimore with the Ohio River at such important gateways as Pittsburgh and Wheeling.

With all the natural advantages, the North Atlantic States must sooner or later have turned from agriculture and shaped their industries largely for manufacturing. But in the early days there was still commerce, shipbuilding, and fishing to engage the productive activities of the people. With numbers of fine harbors and a wealth of timber, shipbuilding was bound to thrive. Fish were always in demand in Europe, and with the lumber and agricultural supplies of this region, its ships were guaranteed adequate outward cargoes. To render the inward cargoes sufficient, European manufactured goods had to be carried. Thus New England began to compete with England for the carrying trade of the world.

But the War of 1812 and the Embargo Act very nearly destroyed our fleets. Protected, however, during the war from European competition, manufacturing began to thrive Capital and labor were withdrawn for a while from commerce; and as the country grew and its peculiarly great natural advantages began to tell, the North Atlantic States soon gained preëminence in the manufacturing industries.

When we turn from the North Atlantic to the Southern States we find some economic facts reversed. The North Atlantic States are densely peopled; on a relative basis the population of the South is sparse. In the North the manufactured products outweigh the agricultural in importance: in the South the reverse is true. The large cities in the North, as New York, Boston, Philadelphia, are seacoast ports; few of the large cities of the South front the ocean. In the North no single crop holds the preëminence that cotton does in the South, where there is less diversification in agriculture as well as in industries.

The Southern section includes the states south of Mason and Dixon's line and the Ohio, and, in addition, Texas, Oklahoma, Arkansas and Louisiana. In these states there live 50 persons for each square mile of territory, whereas in New England the density of population is 120, and in the Middle Atlantic 223.



Courtesy Bureau of the Census, U. S. Dept. of Commerce

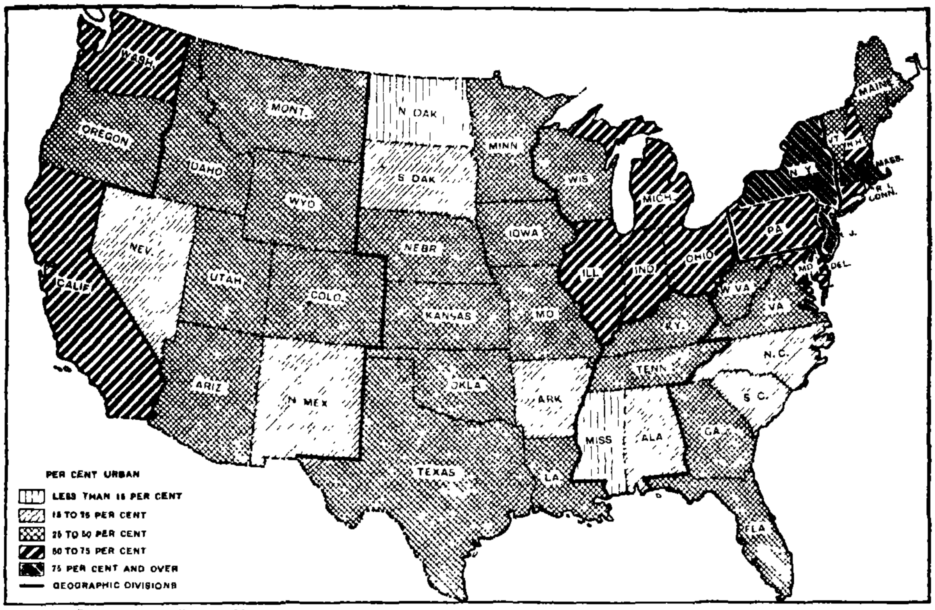
POPULATION OF THE UNITED STATES PER SQUARE MILE, BY STATES, 1920

The area of the Southern section is over four times as great as the North Atlantic, but the value of the manufactured products in the latter accounts for about half that for the entire country. The South, on the other hand, can boast of only a little over one-eighth of the total. But in the value of its agricultural products the South, with over a third of the total crop values of the entire country, holds a notably high position, easily surpassing all other sections with the single exception of the North Central.

It must be remembered, however, that before the Civil War the South was organized on a wholly different economic system, with slavery as the foundation. This made the plantation system profitable and in itself tended to retard the development of manufactures. The Civil War impoverished the South, not only because it drained it of its resources, but because by eliminating slavery it destroyed at one blow a large part of the wealth of the South and undermined its system of economic organization. Aside from that, the Civil War gave a severe setback to the development of manufactures in the South, and little progress was made during the period of political restoration which occupied the two decades immediately following the war — a period of marked industrial expansion in the North.

Since 1880, however, the commerce and industry of the South has progressed by leaps and bounds. The new commercial and industrial South presents in many respects as wonderful a picture of the achievements of human enterprise and progress as can be found anywhere. Since 1900 the manufacturing industries of the South have increased between three and four-fold, whether that increase be measured in capital invested, in horse-power used, in wage-earners employed, or in value of products.

Nevertheless this industrial progress of the South has been made in the face of what might seem to be insurmountable obstacles. As has been said, good harbors are not common on the southern Atlantic. In general the only good approaches to land arise where river channels are drowned by the general sinking of land. But because of the prevalence of sand-bars, these channels require frequent dredging in order to permit the approach of large vessels.



Courtesy Bureau of the Census, U. S. Dept. of Commerce

PER CENT URBAN IN TOTAL POPULATION OF THE UNITED STATES, BY STATES, 1920

Indeed, in the Southern Atlantic States, south of the Chesapeake, the most important cities, such as Richmond, Raleigh, Columbia, Augusta and Macon, do not lie on the coast but are situated on the "fall line," on the margin of the coastal plains, where the rivers running to the Atlantic descend from the uplands over a ledge of rock in falls or rapids. This fall line stretches from the Delaware as far as northern Georgia, retreating farther westward from the coast.

In earlier years the fall line got its importance because it marked the head of navigation for large boats and necessitated portage for smaller boats. Now its importance comes more largely from its cheap water-power, which has encouraged the development of manufactures. Nearer the coast, however, we find that such cities as Charleston and Savannah, however, have been and are important ports, and the volume of their commerce is likely to continue to increase as rapidly as it has in the recent past.

The Gulf States are much more favorably situated from the standpoint of ready access to the sea. New Orleans, indeed, stands next to New York in the handling of the country's foreign trade, and its importance is bound to increase. It stands at the foot of the Mississippi River, which, being ice free and of sufficient depth, is likely again to be a great artery of commerce, as it has been in the past. In Texas, Galveston is the natural outlet for the commercial products of a large part of the Southwest. Mobile and Pensacola owe their importance primarily to the large coal and iron deposits around Birmingham; Mobile is growing through the increase of commerce with Cuba and Central America, and Tampa and Key West also owe their commercial importance to this southerly routed trade. Tampa also is situated close to the most valuable phosphate deposits in the world. As the Panama Canal trade develops and commerce is more largely diverted in a southerly direction, these gulf ports are bound to assume prominence as trade outlets of the South and Central West.

In minerals the South is well provided, even though its coal districts probably cannot hope to provide power quite so cheaply as the Pennsylvania and West Virginia deposits do for the manufactures of the North.

But coal can be mined so cheaply there that a great increase in the manufacture of bulky raw materials which cannot be cheaply transported considerable distances is inevitable. At Macon, where water-power is abundant, the manufacture of iron ore has already assumed large proportions. The lumber industry of the South is wresting the leadership from the Great Lakes states. The Louisiana sugar industry has made necessary the development of sugar refineries in New Orleans. The beef from Texas ranches should in time go in larger part to packing houses in such cities as Fort Worth and Dallas. At Charleston the production of phosphate fertilizers has a splendid future.

The South more dependent than other sections upon a few great staple crops

In agriculture, as we have seen, the South is more dependent upon a few great staple crops than are other sections of the country. The principal crop is, of course, cotton. The northern limit of cotton growing follows closely the mean summer temperature line of seventy-seven degrees. Very little cotton is grown where the average frostless season is less than two hundred days. On the west the spread of cotton culture has been stopped approximately at the line where the average annual rainfall is twenty-three inches. Cotton growing demands fertile soil. So we find cotton in the Piedmont and the coast plains of the South Atlantic States, on the black prairie soils of Alabama and Mississippi, in the Yazoo-Mississippi delta, in the Red River Valley of Arkansas, and in the Black Prairie of Texas. Recently the cultivation of fine grades of cotton has been successfully introduced into the Southwest, especially California and Arizona. In many of the states of the South cotton exceeds in value any other crop, or the product of any industry.

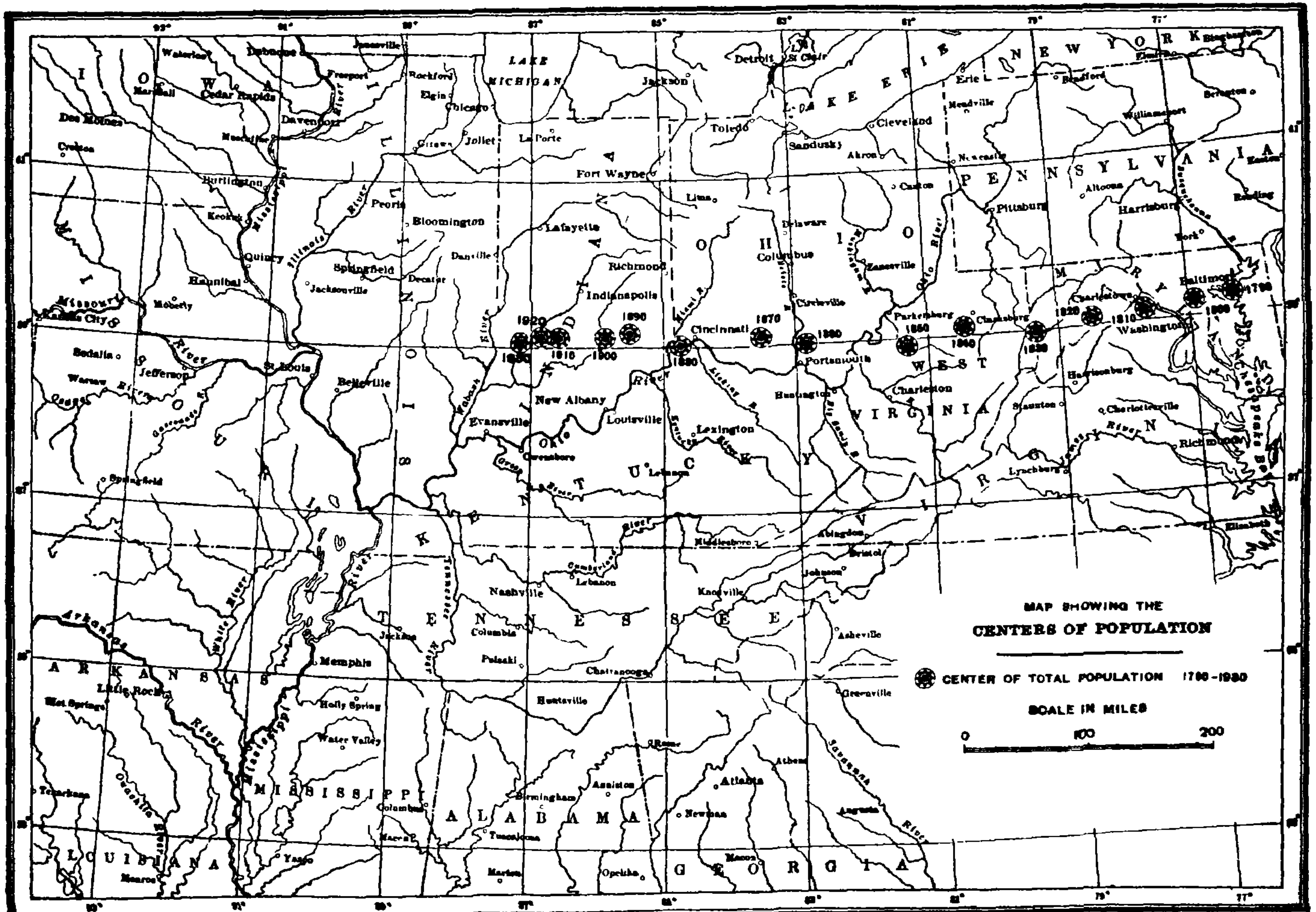
Practically the only limitation in the South upon the production of cotton is the difficulty and expense of securing sufficient pickers; man can cultivate more cotton than can be economically picked. Cotton growing has been so intimately bound up with the history of the South and has been in so peculiar a way the economic basis of its civilization that it is hard to find elsewhere any single crop or product which has the same economic, social, and political significance.

Corn ranks next to cotton, and indeed rivals it, in acreage. Cotton, however, is the principal export. In fact, the United States produces normally two-thirds of the world's cotton. But corn is the chief crop for local consumption. Corn bread and pork form the staple diet of many a southern farm laborer. Winter wheat is also grown extensively in the Appalachian uplands, as well as in parts of Texas and Oklahoma. Although the general climate is not exceptionally favorable to the winter grains, they possess the advantage of not requiring attention during the seasons when cotton is being cultivated.

Just as cotton growing has been the dominating industry of what might be called "the southern South," so tobacco growing has had a similar significance in the northern South, especially in Kentucky, North Carolina, Virginia, and Tennessee. Kentucky produces burley tobacco, used in the manufacture of chewing and smoking brands, while Virginia and the Carolinas grow flue-cured or bright tobacco, used for cigarettes as well as for chewing and smoking. Virginia and Maryland tobaccos, in particular, have an important export market. Such tobacco as is grown in the North, especially in Ohio, Wisconsin, and the Connecticut Valley, is used largely in the making of cigars, as is the high-grade tobacco which is being grown in increasing measure in Florida. Tobacco, like cotton, requires intensive cultivation and hand labor.

Population and geographical structure of the North Central section

The North Central section includes two census divisions, the East North Central and the West North Central. The former is made up of states in the basin of the Great Lakes: Ohio, Indiana, Illinois, Wisconsin and Michigan. The Western North Central States lie west of the Mississippi and include the Dakotas, Nebraska, Kansas, Minnesota, Iowa and Missouri.



Courtesy Bureau of the Census, U. S. Dept. of Commerce

Altogether the twelve states occupy one-fourth of the total area of continental United States and furnish homes for about one-third of its people. The density of the population is accordingly somewhat greater than the average for the entire country.

In geographical structure the most important feature is its unrivaled system of natural waterways. The Mississippi provides a natural outlet to the Gulf, the Great Lakes to the East. No country in the world has more splendid arteries of commerce, and the Great Lakes Basin is already one of the world's greatest trade highways. Measured due east and west, the Great Lakes afford a navigable waterway six hundred miles long. The St. Lawrence in Canada connects Lake Erie with tide-water; in the United States the New York State Barge Canal affords water transportation to New York Bay.

Agricultural predominance of the North Central as compared with other sections

North of the Ohio and the Missouri the soil is mostly of glacial origin. Glacial soil contains rock waste of many kinds. As this slowly decays the quality of the soil is improved. This section is therefore extraordinarily fertile, and its soil is not easily exhausted by tillage. Glacial action has made the surface generally level, and particularly in the treeless prairies of the Dakotas and Iowa grain farming on a large scale is invited. The climate in summer is hot, rapidly maturing the crops, and the cold winters pulverize the soil. No equal area in the world possesses greater natural farming advantages than this. The Middle West is the world's greatest granary.

A few census figures will serve to indicate in striking fashion the agricultural predominance of this section. The two North Central sections contained at the time of the Thirteenth Census two-fifths of the farm land of the country, and the proportion improved is greater than in any other section. The estimated value of its farm property was more than one-half the country's total. The following table brings this out clearly:

THE WAY IN WHICH THE TOTAL VALUE OF FARM PROPERTY IS DISTRIBUTED AMONG THE GRAND DIVISIONS OF THE UNITED STATES

(In per cents of totals for the whole country)

Division	All Farm Property	Land	Building	Implements and Machinery	Live Stock
North Atlantic	9.3	6.4	20.8	17.2	9.1
Southern	21.9	20.8	22.5	23.3	26.9
Western	11.1	12.0	6.0	9.1	12.7
North Central	57.7	60.8	50.7	50.4	51.3
Total	100.0	100.0	100.0	100.0	100.0

In the production of cereal crops this section has no rival. In corn, Illinois, Iowa, Indiana, and Missouri produce more than two-fifths the total for the entire country. In wheat production the first five states, North Dakota, Kansas, Minnesota, Nebraska, and South Dakota, are all in this division. Washington comes next, but is followed by four other states of the North Central division. In oats the leading ten states are in this section, in barley six of the first ten, in rye eight of the first ten. Since cereals represent more than half the total value of the country's crops, the agricultural supremacy of the North Central division stands unrivaled. Altogether the United States produces about three-fourths of the world's corn supply, and it grows more wheat and oats than any other country. Cereals are to these states what cotton is to the South.

Great cities of the Middle West and what made them so, Chicago and Detroit

The Eastern North Central States occupy a prominent position in the country's manufacturing. Their shops and factories produce more than a fourth of the goods manufactured in the country, and employ nearly a fourth of the wage earners engaged in manufacturing industries. The position of the West North Central States in this division is naturally less important.

The large cities of the Middle West are prevailingly lake ports, together with those possessing unusually important positions on the Mississippi, Ohio and Missouri rivers. Of these, Chicago is the greatest, being both the largest food market and the greatest railway center in the world.

About thirty great trunk lines enter the city, and daily several thousand passenger trains arrive and depart from its stations. The location of Chicago at the southern end of Lake Michigan is such as to make it necessary for railways to converge at this point.

Next to Chicago as a lake city stands Detroit. The strait on which it is situated carries the heaviest traffic in the world. From the West it is one of the gateways to Canada. The magic of Detroit's growth from a commercial center of ordinary importance to a magnificent city with over a million population is, of course, bound up with the history of the automobile industry. In this respect men of energy, ability and vision, as well as Detroit's natural advantages of location, must be taken into consideration. In this account of the industrial geography of our country we are of necessity emphasizing physical factors. The significance and influence of these must be taken into account first of all in any scientific discussion of our economic situation and progress. But it is well to remember that economic progress comes only from the cooperation of man with nature. Human energy and ability may often compensate for some measure of natural disadvantage. It is wrong to say that man dominates nature, just as it is wrong to say that nature dominates and defines all human efforts. It is nearer the truth to say that human effort is *conditioned* by nature. The world of nature is a world of cause and effect. The world of human effort is a world of purpose, of striving, and of accomplishment. Human progress cannot be explained unless both factors are taken into account.

Cleveland, Cincinnati, St. Louis, Kansas City, Omaha great commercial centers

Cleveland is another lake city whose industrial rise has been no less marvelous than that of Detroit. Situated with respect to Lake Erie much as Chicago is situated with respect to Lake Michigan, the northern outlet for the densely populated agricultural and industrial regions of Ohio, at the point where the coal of Pennsylvania naturally meets the iron ore of Lake Superior, the rapid rise of Cleveland to the fifth city in point of size in the United States is a striking illustration of the combined influence of natural factors and human energies.

On the Ohio River is Cincinnati, historically as well as in the present, one of the great commercial centers of the Middle West. In its earlier history it was a center of dispersion for the population and the goods that flowed from the East into the new West through the passes of the Alleghanies and down the Ohio River. Now it is the great gateway from the Middle West to the South and Southeast.

St Louis, situated near the point where the Missouri and the Mississippi meet and where the convergence of river valleys has made the entrance of railways easy, close to the coal deposits of Missouri and southern Illinois, is of necessity a great commercial and industrial center. Kansas City and Omaha likewise owe their importance to such a convergence of river valleys. These cities, together with St. Paul and Minneapolis in the Northwest, are distributing points for a large part of the Mississippi Valley, and are the gateways for transcontinental traffic.

West North Central States bound to increase enormously in manufacturing

Despite the natural emphasis upon agriculture, the West North Central States are bound to increase enormously in manufacturing. Industries continually tend to migrate toward the seat of the bulky raw materials. As water-power comes to be more extensively used in manufacturing, the coal advantages of cities further east will become much less pronounced. In the meat packing industry there has already been a marked westward trend, especially toward such cities as St. Paul, Omaha, St. Joseph, and Kansas City. Since the use of compressed air has become common in the chilling of fresh meat, it has been found economical to dress the meat near the cattle feeding areas. Live cattle require more space and more attention and are subject to greater dangers in transportation.

The Western section extends from the Pacific Coast to Texas and the western limit of the North Central division. It occupies about two-fifths of the area of continental United States, but is the home of only a twelfth of its people. It is increasing in population, however, more rapidly than any other section. During the thirty years from 1900 to 1930 it just about tripled in population — the rate of increase, in fact, was more than 290 per cent, while that for the whole United States was a little more than 66.

Topographically this section may be divided into two districts, the Plateau region and the Pacific Slope. The Plateau region is the "land of little rain," and extends as far west as the white crest of the Sierra Nevada Mountains. In all this vast expanse, land is generally arid; it is only in the higher regions that enough moisture is condensed to support the forests. Farming is therefore confined very largely to old lake beds, river-flooded plains, and irrigated districts.

As in the days of Mexican and Spanish domination, agriculture in the Plateau region is subordinated to grazing. The lofty plateaus furnish many of the cattle shipped later to the corn belt for fattening. In wool the Western section produces about three-fifths of the total for the country. Sheep raising may have tended to restrict the growth of the cattle industry; the young sheep crop the grass so closely that cattle cannot graze after them.

Many fertile tracts of soil are to be found in this section and, accordingly, the limitations upon agriculture are largely fixed by the rainfall. To remedy this, the government is continually utilizing the proceeds of land sales in the arid states for the construction of irrigation reservoirs for the impounding of stream waters now running to waste. Dry farming is being extensively developed in certain fertile sections. The science of winter irrigation is also being invoked. The rain of two winters is stored in the soil — if the rain fell in the summer it would evaporate — and held there over one summer by a dust-mulch. In this way a good crop can often be obtained every two years.

The wonderful climate of the Pacific Slope and the fertility of its soil

On the Pacific Slope the climate is oceanic, comparatively cool in summer and mild in winter. This is the only section of the country having really but two seasons, the rainy and the dry. In the great valleys of California there abound many level and fertile expanses sufficiently watered by rainfall. Such tracts are unsurpassed for the growing of wheat. In the past a large part of this wheat went to Great Britain by the long route around Cape Horn. In California wheat growing, however, is yielding in relative importance to fruit growing. This is not because wheat growing has in itself become unprofitable, but merely because fruit growing has become even more profitable. So fertile, so favored in respect to climatic conditions are the lands of California, that it involves an economic waste to use them for other than the most intensive forms of agriculture, such as gardening and fruit growing. Fruit is the most important single product of California; its oranges, lemons, peaches, olives, figs, and grapes give it the fruit leadership of the country. The invention of the refrigerator car has given an enormous stimulus to this industry. The crop is transported in special cars attached to fast trains and distributed through such centers as Minneapolis, Chicago, St. Louis, and New York.

The mineral resources of the West

Another important crop of the West is its minerals. Since the discovery of gold and silver in this region, it has produced about four billions of dollars in gold and silver bullion. California, Colorado, Nevada, Arizona, Montana, and Utah, in the order named, have been the largest producers of gold in recent years. South Dakota is the only state outside of this district with an important gold production. In silver production the leading states are, in order, Montana, Utah, Nevada, Idaho, Arizona, Colorado, and California. The importance of some of these western states as producers of coal has been discussed in another connection.

In the Southwest too, especially in Southern California, there is much petroleum. The presence of this petroleum has been an economic factor of the first importance. It has done much to offset the high cost of coal on the Pacific Coast. Not only is it used as fuel for locomotives, but in an increasing measure it is the fuel for industries, for the heating of homes, and for the production of gas. Its increasing utilization in the bunkers of ocean-going steamers is a commercial fact of the first significance.

It would take too much space to describe in detail the wonderful mineral wealth of this western region. The rarer as well as the commoner minerals are found in extraordinary abundance and variety.

Columbia and Sacramento among the few western navigable river systems

The navigable waterways of the West are few, as the country is in the main a lofty tableland. The Columbia and Sacramento river systems are most fortunate exceptions to this statement. The Columbia is navigated by sea-going vessels as far as Portland on the Willamette, and by river steamers to Lewiston on the Snake. In the absence, however, of a general system of inland waterways, western industrial development depends largely on the railroads.

High freight costs are at once the salvation and the handicap of local manufactures. They prevent to a certain extent the competition of eastern finished goods. Likewise they prevent western manufactured products from seeking eastern markets, except in cases where the power of the West, either coal or water, can be cheaply obtained. Manufactures in the Far West are accordingly, for the most part, dependent upon the western market for the disposal of their output.

Pacific Coast ports that offer enormous future possibilities

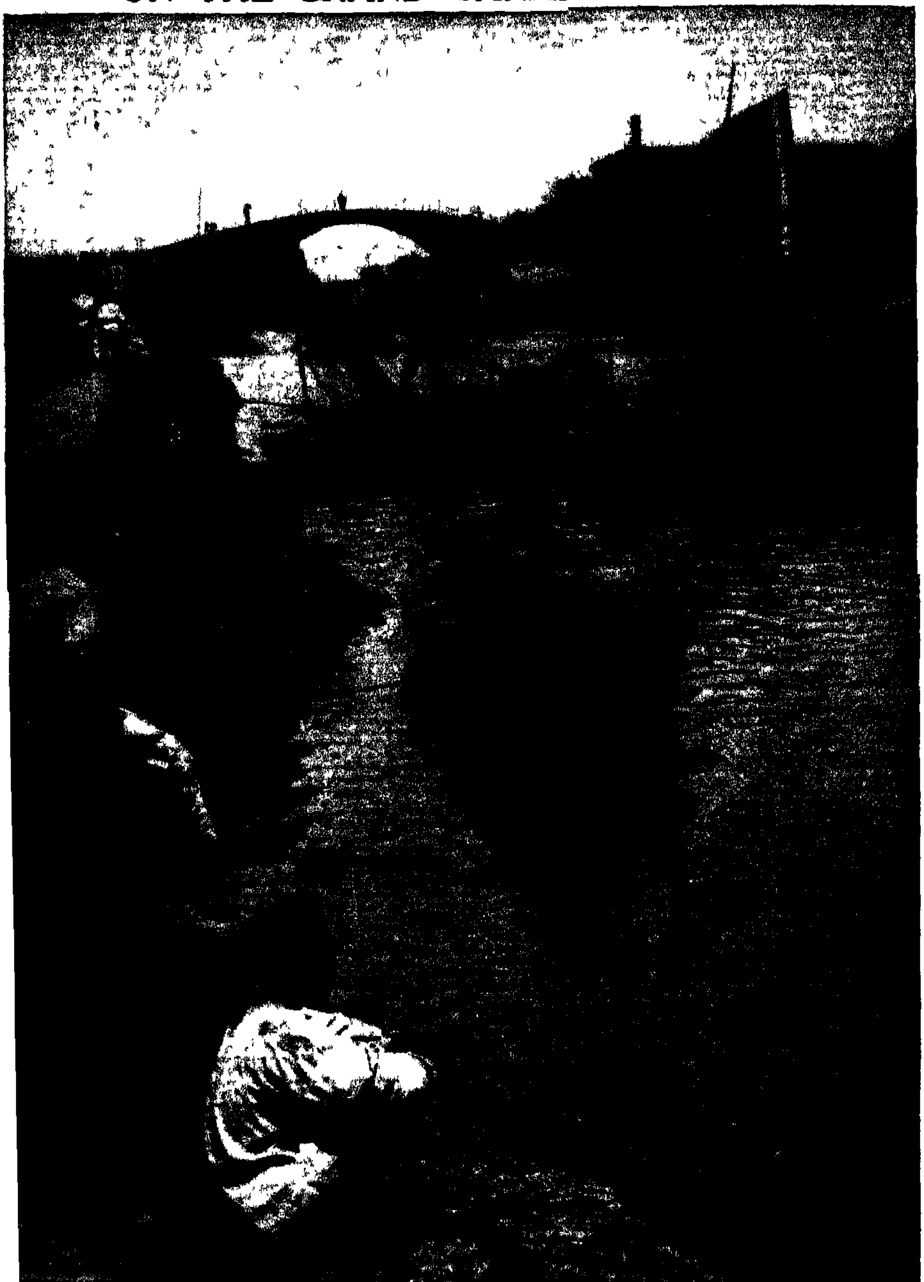
The Pacific Coast is characterized by mountains rising straight from the sea. It is at most points rugged and forbidding and might therefore seem to be unfavorable to commerce. Only in three places — Puget Sound, the mouth of the Columbia, and San Francisco Bay — is it pierced by navigable rivers. Here lie ports of enormous future possibilities. Spokane and Walla Walla are commercial centers on the Columbia River. At Spokane railways converge which gather the wheat and the grain of the "inland empire." San Francisco Bay and Puget Sound afford naturally better harbors, larger and more accessible, than New York. Steamship lines connect them to Panama, the Hawaiian Islands, Japan, and Australia. They are the centers likewise of a large coastwise ocean traffic. Other ports of importance are Los Angeles, where human energies have made a splendid harbor where nature had been none too generous, and San Diego, whose natural harbor is one of the safest as well as one of the most beautiful in the world.

What further development of irrigation, minerals and water-power will do

As the fertile areas of the Far West are more extensively developed by irrigation and dry farming, as its mineral wealth is more and more drawn upon, as our Pacific traffic increases, the West is bound to increase enormously in population. Local manufactures must also grow with the increasing density of the population. Discovery of new coal fields, more scientific utilization of the old, and the more extensive development of its water-power facilities may in time do much to overcome its relative disabilities in respect of power manufacturing.

Of all the natural divisions of the world few even approach North America in physical endowment And the United States occupies the heart and the richest portion of the continent. With its untold mineral wealth, its preëminence in coal and iron, its vast fertile plains, its strength in cereals and cotton, its magnificent ports and internal waterways, the United States has been so richly endowed by nature that its peoples must feel that before them lie not only magnificent opportunities but also responsibilities of wise use and trusteeship, which, rightly viewed, are equally splendid.

ON THE GRAND CANAL OF CHINA



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LOOKING TOWARDS THE NITU BRIDGE AT SOO CHOW

THE WORLD'S GREAT CANALS

The Use of Artificial Waterways to Facilitate Trade and Travel

INLAND CITIES TRANSFORMED TO SEAPORTS

PRIMITIVE man was not long in discovering that transport for himself and his worldly goods was much easier and quicker by water than land, even with the aid of beasts of burden; and very early in his history we find him supplementing the natural facilities by digging canals to connect already existing waterways. As the size of his vessels grew and as he obtained more complete mastery of the sea, the economic importance of connecting inland waters with the sea and of connecting different parts of the sea itself by means of canals became more obvious. The first canal systems, no doubt, were built for irrigation purposes, and some of these were constructed at a very early date. Even if we regard as somewhat legendary the assertion of some Egyptologists that the ancient ruler of Egypt created a canal system as early as 1000 B.C., it is quite certain that the Egyptians, Chaldeans and the Chinese had well-developed artificial waterways many centuries before the Christian era.

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ON THE BANKS OF THE GRAND CANAL OF CHINA

Undoubtedly these irrigation canals were soon used for transporting goods and we have authentic records of great canals expressly constructed for commercial purposes many thousands of years ago. Noteworthy among these is that which connected the Nile with the Red Sea, dug about 600 B.C and in use until 767 A.D., when the Mohammedan caliph Al-Mansour ordered its destruction, thus perpetuating his name as a doer of evil.

The great canal system of China was begun probably in the seventh century. The Grand Canal which connects the capital with the sea at Canton and branches to many other points was finished toward the end of the thirteenth—after being about 600 years under construction. Including canalized rivers this canal system exceeds a thousand miles in length. Other lesser systems bring the total for China's canals to 5300 miles, all of which have been in constant use for many hundreds of years and have been invaluable in the practical solution of the transportation problems of this teeming land of some four hundred million inhabitants.

Thousands of people forced off the land live in boats on the canals. Their waters furnish an abundant supply of fish; while the muck drawn from their beds is much valued as a fertilizer for the hard-worked soil.

The importance of connecting large bodies of water by means of navigable canals was often recognized long before it was possible to carry some of these projects into successful execution. Thus the Corinth Canal, which connects the gulf of that name with the Saronic Gulf and is only 4 miles long, was begun by Nero in 67 A.D. but left unfinished. A French company took up the work in 1881 and it was only completed by a Greek company in 1893. It has not been as useful as anticipated because of the swift currents that sometimes flow through it.

Photo Brown & Dawson

MONUMENT TO FERDINAND DE LESSEPS

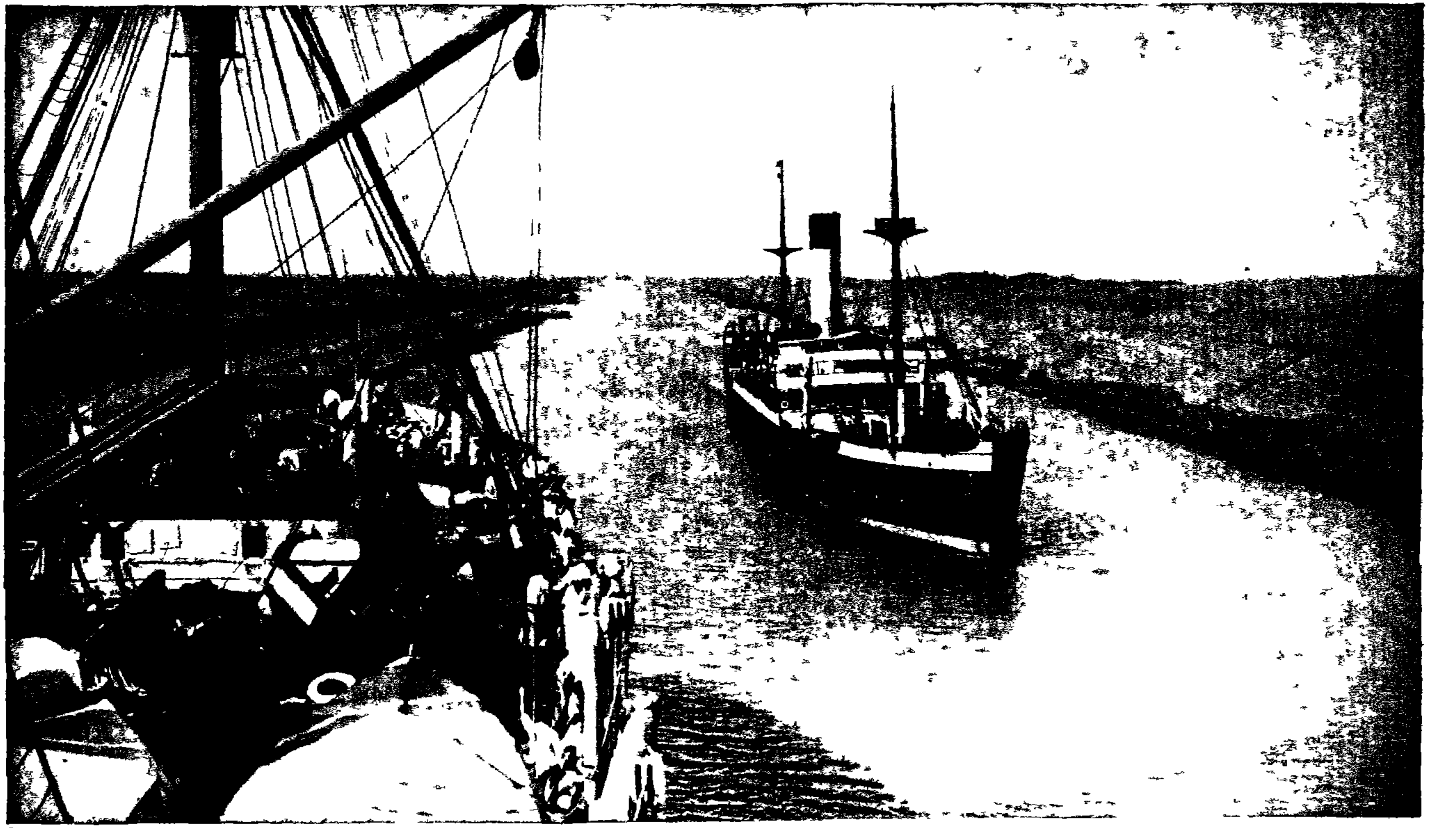
This statue of the distinguished French engineer stands at the Port Said entrance to the Suez Canal, conceived and built by him, "one of the most powerful embodiments of the creative genius of the 19th century"

The importance of a canal across the Isthmus of Suez must have been evident to many ancient peoples. It remained for the distinguished Frenchman Ferdinand de Lesseps to plan and carry to successful execution this great project The Suez Canal connects the Mediterranean and the Red Sea and thus eliminates the long ocean voyage around the Cape of Good Hope, shortening the distance to India by one-third. Its opening in 1869 was an epoch-making event and until the completion of the Panama it was the most important of the world's canals, and will probably remain so for some time in point of tonnage passing through.

The Suez is a sea-level canal large enough to accommodate ocean-going vessels. It is 103 miles in length, 35 feet in depth and 108 feet in width at the bottom. Its estimated cost was $147,000,000, and as many as 5373 vessels with a net tonnage of 20,275,120 have passed through it in one year. The canal has been a highly profitable undertaking. It is owned and operated by a French company in which the British government holds a controlling interest: a military asset of immense value.

The European nations began their work on artificial waterways about the twelfth century, the Dutch being among the first to see their advantage. The low lands of Holland and Belgium are by nature peculiarly adapted to this form of transportation and to this day the mileage of canals, compared to the total area, is greater in these countries than in any others and these "low countries," together with north-

THE SUEZ CANAL, SHORTENING THE MARITIME ROUTE TO INDIA



A long straight stretch of the Suez Canal, which connects the Mediterranean and the Red Sea Two steamers are shown passing near Port Said

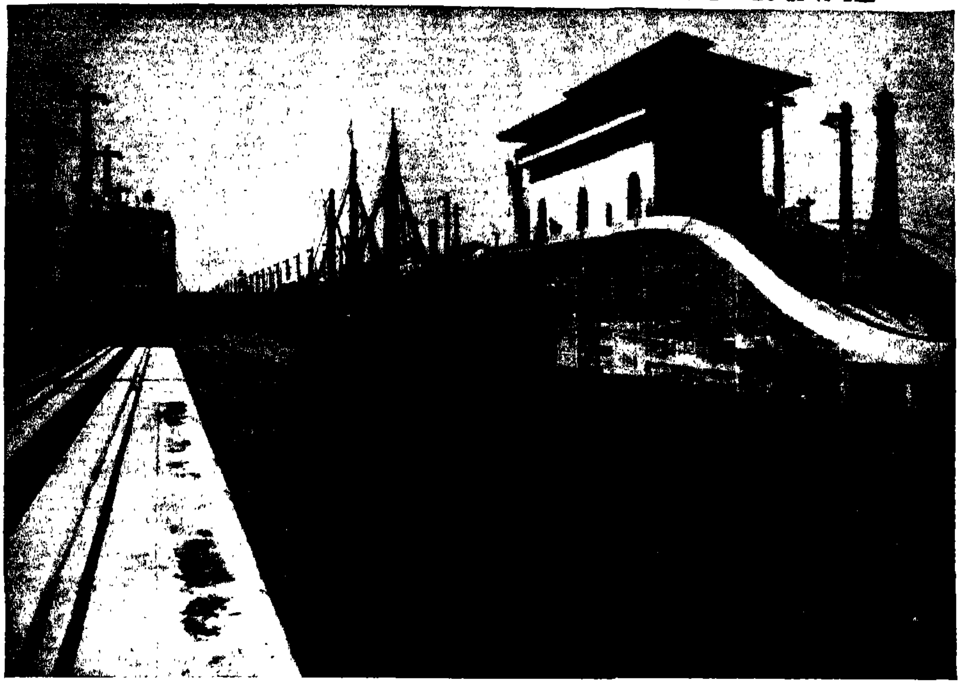
ONE OF THE MASSIVE MOVABLE DAMS AND LOCKS IN THE ERIE BRANCH OF THE NEW YORK STATE BARGE CANAL

The Erie Canal, from Crescent westward to a point near Utica, is a canalization of the historic Mohawk River.

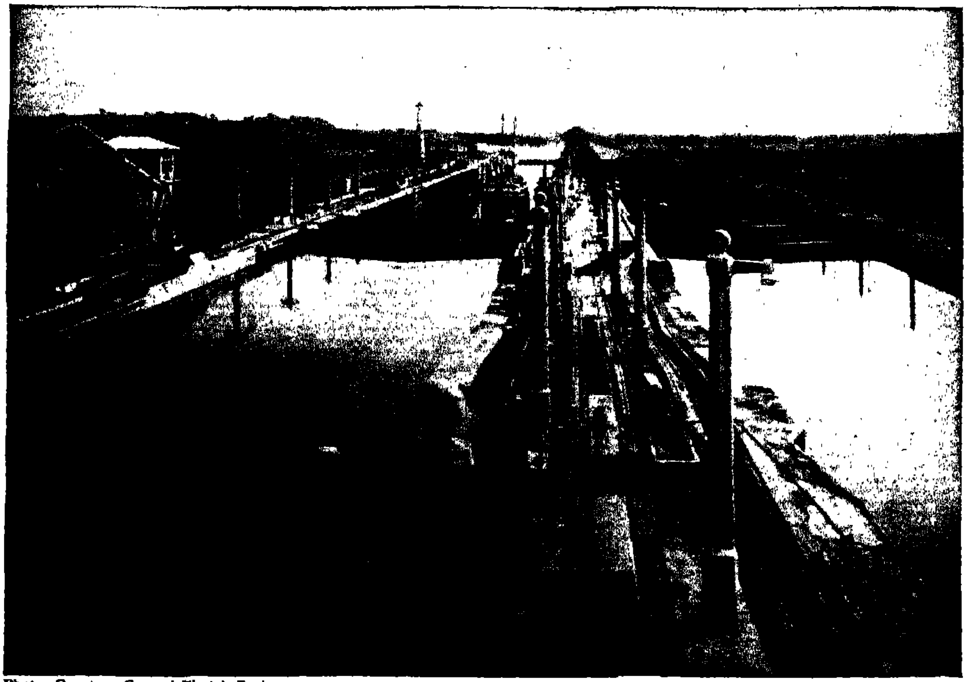
eastern France, had a very complete system of commercial canals by the middle of the thirteenth century. Up to this time, all such canals had been dug between natural bodies of water whose level was the same, or at least so nearly the same that the current caused by the difference was not sufficient to be troublesome. The invention of the "lock" gave a great impetus to canal building, as by means of this device canals could be built connecting waters of different levels, and hence could be carried over elevations instead of digging the earth away so as to secure a uniform level. The invention of the lock is claimed by both the Dutch and the Italians, the former asserting its first use was by them in 1381.

A lock is a box-shaped structure of masonry or concrete, the sides of which are parallel to the length of the canal, built into it at the point where it changes level. The floor of the lock is continuous with the bed of the lower level of the canal while the side walls rise as high as the banks of the upper level. At each end of the lock are water-tight gates. When it is desired to raise a vessel from the lower to the upper level the upper gates are closed and the lower gates opened. The vessel is then run into the lock and the lower gates are closed behind it. Water is now admitted from the upper level usually through auxiliary gates and passages, and, as the lock fills, the vessel rises until it reaches the upper level of the canal. The upper gates are then opened and the vessel emerges from the lock at that level. If, now, while the lock is filled with water a vessel is run into it from the upper level and the gates closed behind it, the water in the lock can be drawn off until the vessel slowly drops to the lower level, when the gates there can be opened and the vessel moved out into the lower reach of the canal. By a series of such locks any elevation can be overcome, provided there is a sufficient supply of water at the upper level to replace the amount lost each time the lock is emptied. In the case of large locks, where the loss is great, some natural stream is usually made available for their operation.

GATUN LOCKS IN THE PANAMA CANAL



U. S. S. *SEVERN* (TENDER) LEAVING UPPER EAST CHAMBER IN TOW OF ELECTRIC LOCOMOTIVES



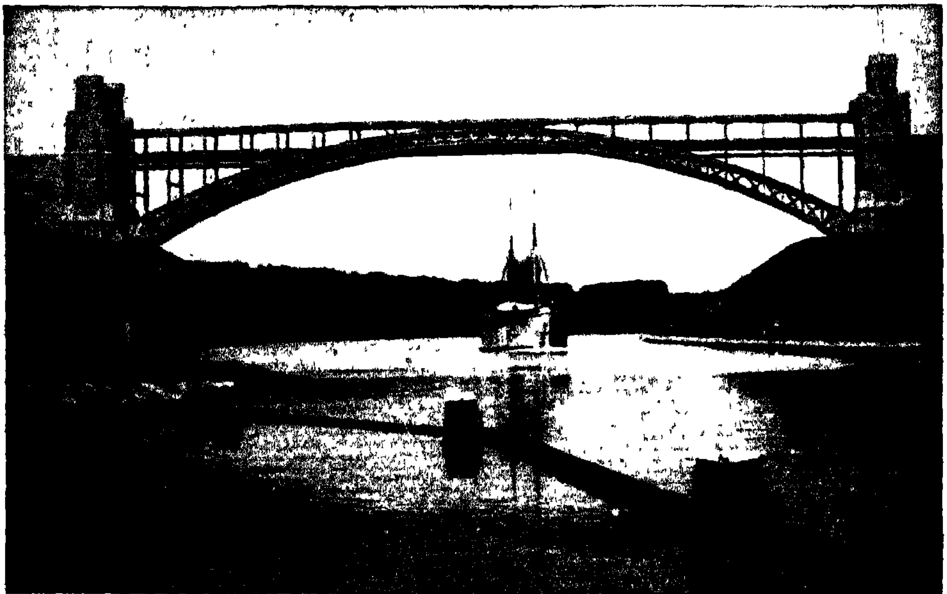
Photos Courtesy *General Electric Review*

OPERATION OF GATUN LOCKS

Looking north from Center Wall Lighthouse, S. S. *Aliança* in Upper West Chamber. Water elevation 56.6 feet.

Practically every European nation has shown great interest in canal building, but the most noteworthy European canals are the Kaiser Wilhelm (Kiel) Canal in Germany and the Manchester Ship Canal in England. The Kiel Canal, which connects the Baltic with the North Sea, was begun in 1887 and completed in 1895 at a cost of over $37,000,000. It was reconstructed in recent years and now has a minimum depth of 36 feet, a bottom width of 144 feet and a surface width of 335 feet. It is 61 miles long. Previous to the Great War it was much used commercially.

The American pioneers were not slow to appreciate the value of canals, and before the advent of the steam railway there was much activity in their construction. The most noteworthy of these earlier American canals are the Cincinnati and Erie, the Chesapeake and Ohio, and the Sault Ste. Marie. Many other smaller canals were cut and a number of rivers canalized. In all about 4500 miles of canals have been constructed in the United States, and for many years they were an important factor in the commerce of the country. But now nearly 2000 miles of American canals have had to be abandoned largely because of railroad competition. But though the American continent cannot claim precedence for the length of its canals, it is here that the greatest of such works have been undertaken: the Panama Canal; the reconstructed Erie or Barge Canal, and the great system of canals now being constructed by the Canadian government to make a waterway, navigable for large vessels, from the Atlantic Ocean to the Great Lakes.



(c) Underwood & Underwood, N Y

THE KIEL CANAL WHICH CONNECTS THE BALTIC WITH THE NORTH SEA

The Manchester Ship Canal in England while only 35½ miles long is one of the most remarkable artificial waterways ever constructed. Five sets of great locks overcome an elevation of 58½ feet between Manchester and the sea, and the canal makes Manchester a seaport. The original cost of this undertaking was about $85,000,000. Over 3½ million tons of seagoing vessels passed through this waterway in the year 1919. The total mileage of navigable canals and rivers in Europe is estimated to be about 77,000 miles, of which 13,000, about half the total world mileage, are canals.

The natural outlet of these inland seas, the St. Lawrence River, is obstructed by several long and dangerous rapids, or

THE WELLAND CANAL NEAR ST CATHARINES

"saults" as the French settlers called them, between Montreal and Lake Ontario The Niagara Falls form a barrier to navigation between Lake Ontario and Lake Erie, and the Sault Ste Marie bars the way between Lake Superior and Lake Huron The Canadian government has constructed a series of canals around all of these obstructions, thus giving a waterway for fair-sized vessels from the ocean to Port Arthur at the head of Lake Superior – a distance of 2217 miles The difference in level overcome is above 600 feet and there are 48 locks in the chain

Among the best known of these canals are the Sault Ste Marie and the Welland, the latter overcoming the obstruction to navigation of Niagara Falls The Sault Ste Marie Canal is only 7472 feet long, but it has a single lock 900 feet long, 60 feet wide, with a rise of 18 feet, so that it can accommodate the large steamers that ply between Lake Superior ports and the lower lakes The Welland Canal as it now exists cannot accommodate these large vessels, and the Canadian government is digging a new Welland Canal at a cost of $50,000 000, with a depth of 25 feet enabling the larger vessels to reach Lake Ontario

PORT COLBORNE AT SOUTHERN (LAKE ERIE) END OF THE WELLAND CANAL

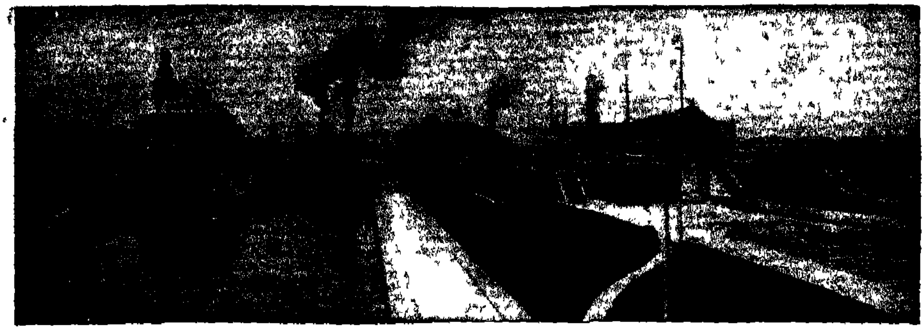


Photo A E Young

ST MARYS FALLS CANAL LOOKING UPSTREAM

Weitzel lock (at left) Poe lock (vessels leaving upbound), Davis and Sabin locks (downbound lockage)

ports The St Lawrence canals at present will handle only comparatively small vessels, but it is planned to enlarge these canals so that big lake steamers can pass directly through to Montreal and Quebec Without doubt the time is not far distant when ocean-going steamers will be able to pass up the St Lawrence to all points on the Great Lakes, load cargoes and proceed to sea The possibility and probability of such a canal system should be borne in mind in evaluating the competing system of American canals which also connects these inland waters with tide-water

The American canal around Sault Ste Marie is also a large one, 25 feet deep, and can accommodate the biggest lake craft It is of interest to note that the combined tonnage passing through the two canals at "The Sault" is about four times that passing through the Suez Canal, although the latter is open all the year round while navigation through the former is only for eight months The major portion of this traffic consists of iron ore from the Lake Superior region bound for lower lake ports and of coal from the lower lake ports for the Lake Superior region A considerable portion however, consisting largely of the grain from the great western wheat fields finds its way to tide-water to be exported to Europe, and it is this that makes the ocean connection of these lakes of greatest importance

The problem of connecting the Great Lakes with the seaboard through Canadian territory consisted simply in canalizing the St Lawrence River the entire length of which lies almost wholly in Canada The problem on the American side, however, involved the digging of much longer stretches of canals as well as the canalizing of several streams

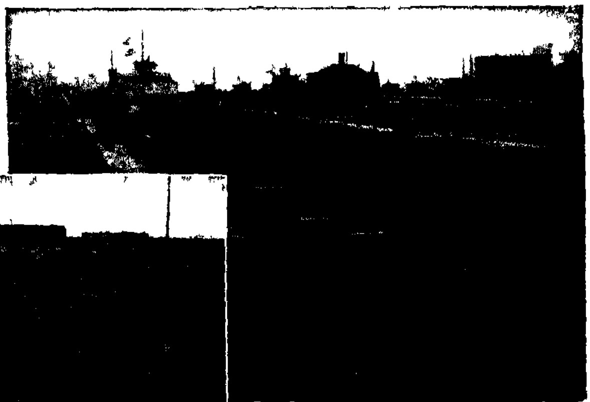


Photo A E Young

SABIN LOCK, ST MARYS FALLS CANAL

At left ready for filling with water, at right, opening of lock on September 18 1919

WELLAND CANAL SEEN FROM THE AIR

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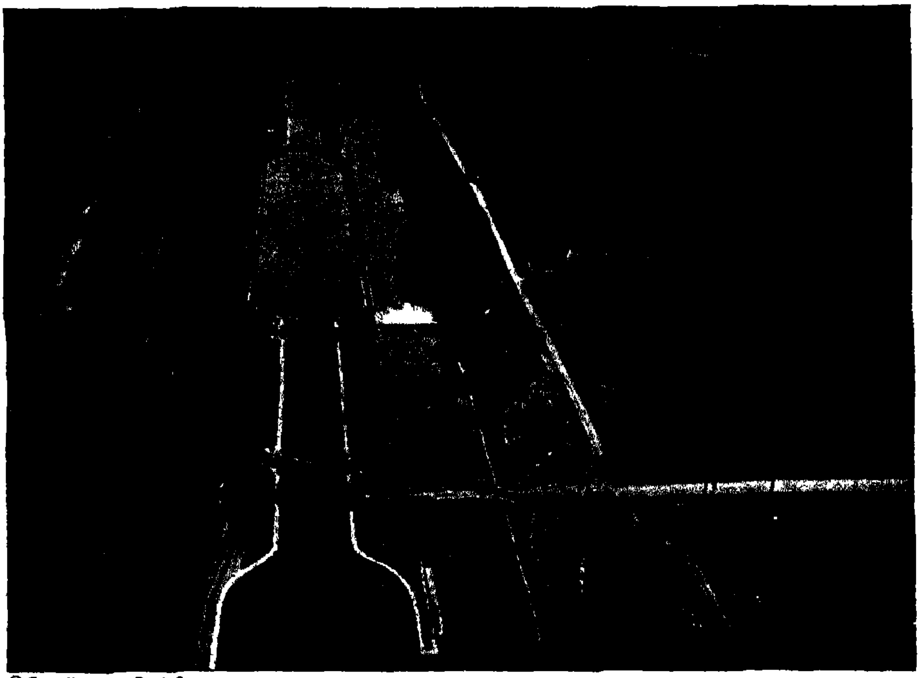
OLD WELLAND CANAL, ST CATHERINES, ONTARIO



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NEW WELLAND CANAL NEAR ST. CATHERINES

These interesting views were taken from an airplane by Mr. Sydney Bonnick.

Time consumed at the end of the 18th century to go from New York to Oswego

It is said that George Washington was one of the first to appreciate the importance of connecting the Great Lakes with the Atlantic by way of the Hudson and Mohawk rivers for the purpose of holding more closely the allegiance of the settlers in the western section. The actual building of the canal, however, was prompted by the somewhat more narrow desire of securing for New York City a large share of the export trade of the inland region. In 1791 the legislature of the state of New York sent engineers to report on the possibility of a canal between Albany and Lake Erie, and the report of this commission was favorable. It is interesting to compare the time consumed in traveling in these pioneer days with that of today. From New York City to Albany required from two to five days by the Hudson River; from Albany the road led overland to Schenectady, 17 miles distant; from this latter point it required nearly a week to pole and paddle up the Mohawk River to Utica, a distance of 104 miles; and it required another nine days to journey by land and water to Oswego on Lake Ontario. It cost about $50 a ton to carry freight from New York to Oswego in those days.

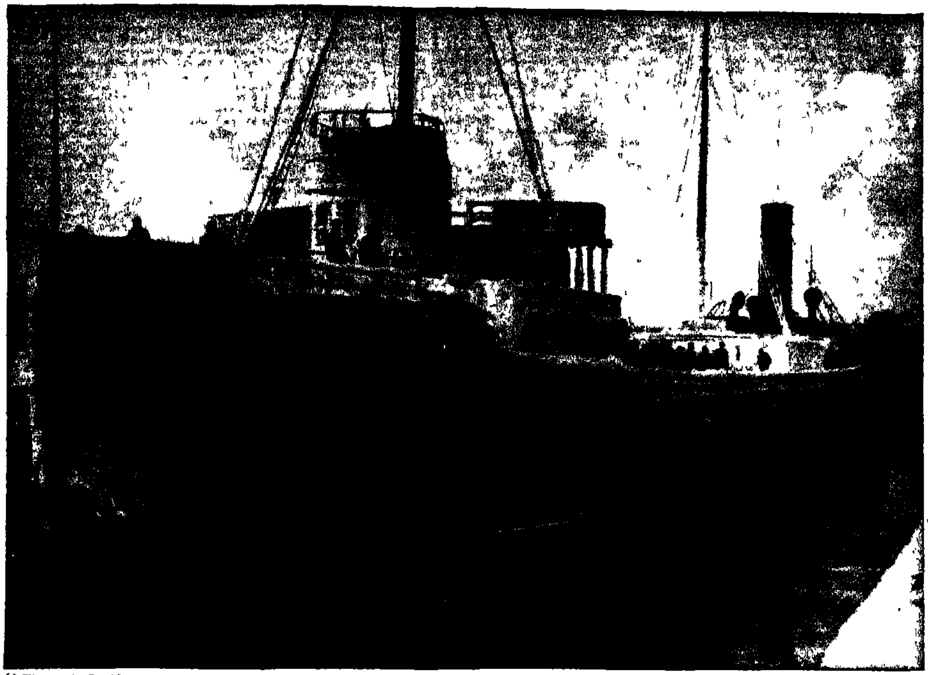
The first attempts to dig the canal were made by private companies, but only a comparatively small part of the work was accomplished, and it was nearly twenty years before the state again took action in the matter. In the meantime Gouverneur Morris, then United States senator from New York, had become greatly interested in the project; and through him DeWitt Clinton, who was destined to be the great promoter of the canal, also became an enthusiastic supporter.

The cost of the canal was estimated at $5,000,000, a very large sum for those days, and an effort was made to obtain the support of the federal government. The War of 1812, however, cut off the possibility of federal aid, and DeWitt Clinton began an agitation to have the canal dug by the state of New York.

DeWitt Clinton reduces the time from Buffalo to the Atlantic to nine days

In 1816 a Canal Commission was appointed by the governor with power to raise a loan guaranteed by the state, and he placed Clinton at the head of the commission. It was found to be difficult if not impossible to borrow money, and progress again stopped. In 1817 Clinton appeared as a candidate for the governorship, pledged to dig the canal if elected. He was elected by the enormous majority of 43,310 to 1479, a most extraordinary expression of public confidence, and three days after his inauguration he went to Rome on the Mohawk River and began the digging of the canal by turning up the first spadeful of earth. He was not able to fulfill his promise that the canal would be finished in 1823, progress being slower then he had anticipated, and his supporters became discouraged. There were many people who doubted the feasibility of the canal, saying "you cannot make water run up hill," not understanding the theory of canal locks. At the next election Clinton was returned to office by a small majority and at the succeeding election he was not even nominated. His enemies came into power and removed him from the Canal Commission. But Clinton was not one to be easily set aside, and in 1824 he again appeared as a candidate for governor and was elected by a large majority, indicating that the people really wanted the canal. He now took up the prosecution of the work with renewed vigor and in 1825 the canal was completed — a monument to Clinton's unfailing faith and dogged determination.

The canal was a commercial success from the very beginning. By the end of 1837, twelve years after its opening, it had paid into the treasury $15,000,000, which was more than the total cost of digging and maintaining it up to that time. The canal proved of great benefit also to New York City. In 1822 the cost of transportation between Buffalo and Albany was $22 per ton; by 1835 it was down to $4 per ton, and the diversion of traffic to the port of New York was assured.



© Photo A L Young

WINTER CONDITIONS ON THE ST. MARYS FALLS CANAL

The Erie Canal was without doubt very largely instrumental in the making of New York City the greatest seaport on the Atlantic coast. Its influence on the state in general was even greater. Central New York was populated so rapidly that in a short time nine-tenths of the people of the state lived near the canal. It became a region of enterprise, a characteristic it still retains. Clinton was, of course, highly honored, and re-elected governor, dying in office in 1828. His breadth of vision has been more greatly realized as time has gone by, and his name has been given a high place in the history of his state and country.

The success of the main canal stimulated the construction of several important branches, thus connecting all the important inland waters of the state by a canal system nearly 1000 miles in length and second only to the Grand Canal of China in this respect. It was soon apparent that the canal was not large enough for the business offered, and agitation began for its enlargement.

This resulted in 1835 in the legislature authorizing it The estimated cost of these improvements was placed at not less than $12,500,000. The story of this effort is one of extravagance and political "graft," and $12,000,000 were expended without producing any practical results. What may be regarded as a greater evil was the lowering of political morals due to this lavish waste of money, which for a long time prevented the carrying out of the plan.

In 1849, however, after these very many years of wrangling and waste, the enlarged canal was opened. The original canal was 40 feet wide at the surface, 4 feet deep, and could accommodate barges of 30 tons. The new canal was 70 feet wide at the surface, 7 feet deep, and could handle barges of 240 tons burden. This meant an increase in the capacity of wheat barges from 1000 bushels in the primitive stage to 8000 bushels. The enlargement cost $33,000,000, which was a very large sum for those times, especially for a single state to assume.

And yet the increased traffic undoubtedly would have warranted the expenditure if other influences had not intervened. In the meantime railroads had been making rapid progress, and by 1841 New York and Buffalo were connected by a somewhat primitive railway system This form of transportation was, of course, much more rapid than water transportation, and this feature, combined with aggressive competition and opposition to the canal by those interested in railways, brought about legislation adverse to canal traffic By the end of the century the canal had almost ceased to be an important factor in transportation

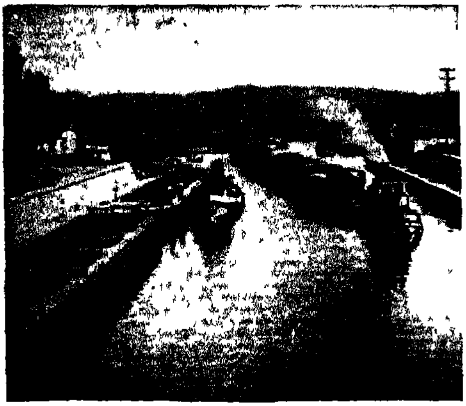
There were many people, however, who still had faith in the canal as a state and national asset, and in 1903 the question of enlarging it at a cost of $101,000,000 so as to accommodate 1000-ton barges was submitted to popular vote In spite of this enormous estimated cost the measure was approved and the work of widening to 112 feet and deepening to 12 feet begun. The reconstructed canal was officially opened in May, 1918 The cost greatly exceeded the original estimates It is an index of our great prosperity that one state can, without jeopardizing its credit, carry through such a colossal undertaking Its immensity has been thrown somewhat into the background by the great publicity given to the Panama Canal, and because of the international character of this latter enterprise As a matter of fact, however, some of the engineering and constructive features of the new Erie Canal compare favorably with anything that has been done at Panama Thus the locks at Waterford will lift the vessels transported 169 feet in five successive steps, which is twice as great as the total lift of the Panama locks combined The lock at Little Falls on the Mohawk River is one of the highest in the world, being 40½ feet, and the time of lifting a vessel is only eight minutes. There are 57 locks all told, and the majority have a lift of 16 to 20 feet They have a maximum inside width of 45 feet, a length of 306 feet, with a depth of 12 feet of water over the sills. Their barge capacity is approximately 3000 tons.

What the New York State Barge Canal needs to make it a sure success

Experience indicates that barges 100 feet long, 21½ feet wide, with a loaded draft of 9½ feet, best meet navigating conditions. A fleet of six such barges, one being a power boat, can be passed through a lock at one time, and the total capacity of the fleet would be approximately 2500 tons. Larger barges utilizing the locks to full capacity may be advantageously operated for special purposes. As there are no towpaths on the new canal it is necessary to propel all barges by mechanical means. Trips may be made from Buffalo to New York in from three to five days

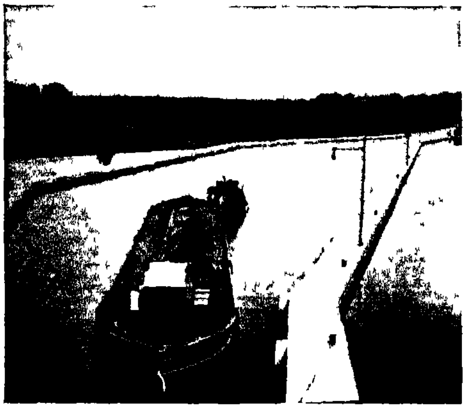
The possibility of the new barge canal being a great financial success is, of course, somewhat problematic The hope that the enlarged waterway would regain its old grain-carrying trade may not be fully realized, partly because of the railroad competition and partly because of the Canadian canals Certainly if these latter are enlarged, as they undoubtedly will be, so as to permit the passage of ocean-going vessels to the upper Great Lakes, the export grain trade will not be likely to go through the Erie Canal Furthermore, while it may cost less to move freight through the canal than it does by rail, the great demand for speed, which is one of the chief characteristics of modern business, gives the railway a decided advantage The railways also offer service all the year round, whereas waterways in the northern regions are closed a large part of the year Railways also can cover the country with a network of branches which give service to a wider range of territory than can ever be possible with waterways Nevertheless, there is an immense amount of freight which does not need to be moved rapidly, and with the rising cost of coal there can be little doubt that this great waterway can be made to justify the expense of its construction without much reference to transatlantic freights A large factor in the financial success of this magnificent undertaking will be the wisdom with which legislation is enacted to govern the conflicting interests of all common carriers.

NEW YORK STATE'S GREAT WATERWAY



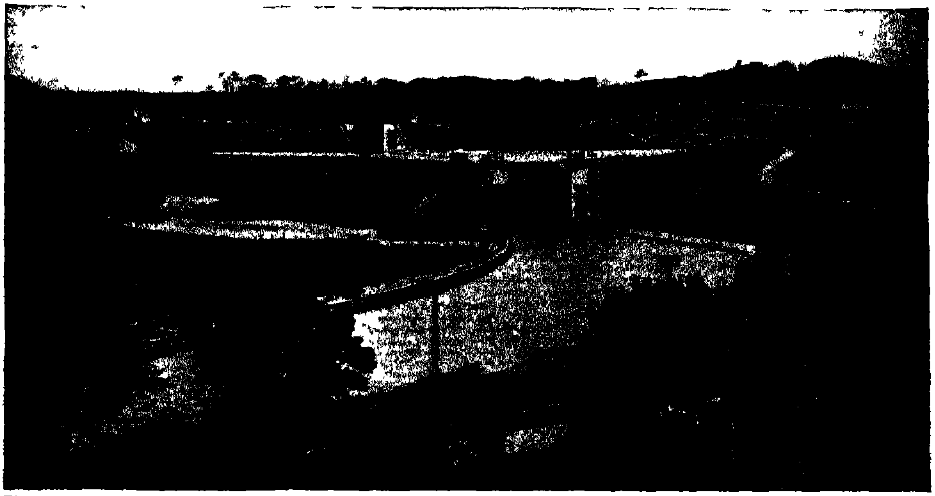
United States Government steel barges each of which will carry as much as 20 freight cars passing in the Barge Canal

Tandem locks at Lockport N Y with a combined lift of 48 feet replacing the five old Erie Canal locks on the right



Type of oil tank barge which is being successfully used on the New York Barge Canal

650 ton steel barges towed by modern self propelled barge on the Erie branch near Rochester



Three of the massive new locks comprising the Waterford Series at the eastern terminus of the New York State Barge Canal There are five locks in this series, and these have a combined lift of 169 feet, double the total lift of the Panama locks

The story of the Panama Canal is the story of one of man's greatest achievements, made possible only by modern constructive methods and modern knowledge of sanitary precautions. It is important to note that the latter played fully as important a part in this undertaking as the former. As in the case of the Suez Canal, the commercial advantages of the Panama Canal were obvious, and the earliest Spanish explorers after vainly seeking a natural water passage in these regions began to speculate as to the possibility of digging a canal and so connect the two oceans. Charles V ordered a survey made in 1520, but the unfavorable report of the Spanish governor at Panama caused him to abandon the project. Several plans were brought forward in the succeeding years and it had long been much debated in the United States.

In 1878 French interests obtained a concession from the Colombian government to construct a canal and work was actually started in 1881 under Ferdinand de Lesseps. The story of this venture is one of the most amazing and at the same time one of the most painful in engineering annals. It is a tale of extravagant and foolish expenditure, of stock jobbing and graft, and of stupendous blunders in technical and business management. Long before the date set for the completion of the canal the company was bankrupt, and de Lesseps with his son and other directors had been sentenced to imprisonment. A later trial released them.

In the meantime private interests in the United States had obtained a concession to build a canal in Nicaragua. This attempt proved abortive though several million dollars were spent in the venture, and finally the United States government authorized the construction of an isthmian canal and the acquirement, if possible, of the French interests. President Roosevelt negotiated a treaty with the Colombian government whereby a strip of land five miles wide on each side of the canal was acquired. The United States was to pay $40,000,000 for the French interests and $10,000,000 to Colombia for the canal rights. After nine years Colombia was also to receive a yearly stipend of $250,000. Just when the treaty was about to be consummated the president of Colombia called his congress together and had the treaty rejected, hoping to drive a better bargain. But at this juncture the State of Panama, which was most concerned, seceded from Colombia and took the matter into its own hands. The new government was promptly recognized by the United States and a treaty similar to that negotiated with Colombia was at once signed. As the United States took immediate possession of the Canal Zone any aggressive action on the part of Colombia was out of the question. This prompt action on the part of the United States has been much criticized, but there can be little doubt that history will fully justify the action. The project was far too great a matter to be held up by the petty bickering of a dictator whose word was valueless and whose every action was suspicious. Work was begun upon the canal on May 4th, 1904.

It had hardly commenced when it was found that something would have to be done to protect the workmen against malaria and yellow fever. No serious effort had been made by the French to combat this problem and indeed the remedies were not known at the time of their operations. It is said that 50,000 men died in the Canal Zone during the French occupancy, of malaria, yellow fever, dysentery and similar ills. Fortunately, medical science had discovered in the meantime the disease-carrying characteristic of the mosquito and under Colonel Gorgas, the surgeon in charge of the medical side of the expedition, a systematic effort was made to rid the Zone of this pest by eliminating its breeding places. Swamps were drained and oiled, garbage was banished, houses were screened and fumigated, and a general cleaning up enforced. Liquor was also prohibited. The results obtained were almost marvelous and the Canal Zone became one of the healthiest of places. The rise in the moral tone of the place was no less marked. Modern science has achieved few successes greater than the sanitary renovation of the Panama Canal Zone.

The French had projected a sea-level canal and the American engineers commenced work with the same idea in mind It was soon seen, however that such a canal would be an immense undertaking and the plans were changed to a lock canal which would elevate the ships 85 feet during transit Even with this change in the grade the amount of earth to be removed was enormous The French had excavated 81 500 000 cubic yards of material, of which about 30 000,000 was of assistance in the new plans There still remained about 210 000 000 cubic yards still to be excavated The United States attacked this work with the largest and most powerful digging machinery ever constructed even in this age of great machinery, and preparations were made to build locks on a scale heretofore never attempted

The canal is 46 miles in length and for 29 miles of its course it runs through hilly country The Atlantic entrance curiously enough lies to the west of the Pacific entrance because of the crooked form of the isthmus A ship entering the Atlantic end of the canal passes up Limon Bay through a channel 500 feet wide and about six miles long to the Gatun Dam which holds back the waters of the River Chagres forming an artificial lake 85 feet above sea level $23\frac{1}{2}$ miles long with an area of about 220 square miles The dam is a monumental construction 7600 feet long 2000 feet thick at the base and 135 feet high An immense spillway provides for the rise of the water in the dam when the Chagres is in flood

The locks at Gatun for lifting the vessels from tide-water to the level of this lake are the largest ever constructed There are three of them 1000 feet long 100 feet wide and 41 3 feet deep placed in succession, each raising the vessel 28 3 feet Over 2,000 000 cubic yards of concrete and masonry were required to construct these giant stairs Each lock is in duplicate so that two ships may go up at the same time The third lock of the series delivers the ship into Gatun Lake, across which a deep channel is cut and where a steamer may proceed at a good speed

THE WORLD'S GREATEST ENGINEERING TRIUMPH

At the end of the lake at Bas Obispo the canal enters Culebra Cut, where the greatest amount of excavating had to be performed and where constant landslides gave great trouble. The channel through the cut is 300 feet wide, 41 feet deep and about eight miles long, terminating at Pedro Miguel where twin locks drop the ship from the level of Gatun to that of Miraflores Lake, 30 feet lower. This small lake is about a mile long and leads to the twin Miraflores locks, which in two steps lower the vessel to the level of the Pacific some eight miles away. The time required to pass a ship through the canal is from 10 to 12 hours.

Excavation was often conducted under difficulties owing to the shifting character of the soil. Thus in 1911, some 17,000,000 cubic yards of earth were removed from Culebra Cut, of which 5,000,000 cubic yards were due to landslides. It is now clear that it would not have been possible for the French to cut the canal with the implements they possessed and under the conditions then existing. In addition to the great fleet of water-borne dredges at each end of the canal over 100 giant steam shovels were at work on land, some of them taking out as high as 3100 cubic yards a day. The arrangements for hauling the excavated material away and disposing of it were also very complete, and some of the devices were very ingenious, one clearing the contents of 20 cars, each holding from 20 to 40 tons of earth, in ten minutes. The working force varied from 35,000 to 40,000.

The equipment of the canal is remarkably complete and so extensive as to deserve more than mere mention. A large power-house operated from the waters of Gatun Lake was built near the spillway of the dam, and this furnishes electrical power for all of the operations connected with the canal, including the opening and closing of the immense lock gates. Among the most interesting features of the canal are the electric control boards in the operating rooms of the locks, each built to represent in miniature the lock it controls. So that the engineer can see on the board every movement as it takes place, including the rising and falling of the water.

The vessels are towed through the locks by electric locomotives that travel on rails beside the lock. An ingenious device prevents a heavy vessel from ramming the gates. Seventy-five feet from each gate is a large chain which can be lifted so as to intercept the nose of the moving vessel. It is controlled so as to yield slowly, and will bring a 10,000-ton ship moving at four knots to rest in about 70 feet. The system of conduits for conducting the water to and from the locks are in themselves a remarkable piece of engineering.

The Suez Canal cost $150,000,000 and the new Erie Canal with its lateral branches cost $134,720,000. The Panama Canal cost $375,000,000, including $40,000,000 paid for the French concessions, $10,000,000 paid to the State of Panama and $27,000,000 paid for sanitary improvements and civil administration of the Canal Zone. The annual expense of operating the canal, including interest on investment and the $250,000 to be paid annually to Panama, is over $19,000,000. If the history of the Suez Canal can be taken as a guide the tolls should in time return these large sums of money to the United States. The Panama Canal brings San Francisco 8000 miles nearer to New York by water and 6000 miles nearer to Liverpool. Asiatic ports and Australia are all brought 2500 miles nearer New York than they are to Liverpool. With the revival of the American merchant marine the canal should be an assured commercial success. No less important is its value as a military asset.

When the canal was dug an effort was made by other nations and by some of our own people to have it made neutral territory. Our government wisely ruled otherwise and has heavily fortified both ends of the canal with some of the most powerful guns ever mounted. The canal was dug by the United States. It is right and just that we should dominate it and secure the full value of the protection that it affords to our great sea coast and the advantage that it will be to the immense merchant marine which we shall eventually possess.

THE MARRIAGE PROBLEM

Shallow Thinkers and Foolish Books Which Would Destroy the Base of Modern Society

LIFE FROM THE CHILD'S POINT OF VIEW

MARRIAGE may be defined as a physical, legal and moral relation between a man and woman, in complete community of life, for the establishment of a family Socially, its end is that of maintaining the species The aim of society, expressed in laws, should therefore be to reduce the physical illegal and the legal immoral unions, with a view to securing the proper home environment for the children It is here that modern literature so often conflicts with modern science From the days when Ibsen with his famous play, "A Doll's House," opened the current discussion on the problems of marriage, nearly every playwright or novelist has assumed that men and women have the right to test their marriage entirely by the degree of pleasure that their union brings to themselves

Thus Ibsen seems to suggest the right of the woman to abandon husband and gratify her cravings for a broader and more stirring life in the world of art, literature, business, or politics Strindberg, on the other hand, has emphasized the restrictions which marriage and the family entail upon the man Bernard Shaw adopts somewhat the latter view in his "Man and Superman," and our American fiction and drama, as well as the Russian and French, are also full of it As Rudyard Kipling put it —

Down to Gehenna, or up to the Throne,
He travels fastest who travels alone

And some centuries earlier Bacon said in the same vein "He that hath wife and children hath given hostages to fortune, for they are impediments to great enterprises either of virtue or mischief"

Having erected, in modern civilized society, so apparently complete a series of defenses against the harsher forces of nature we are sometimes tempted to think that we have entirely escaped from the laws of life In regard to marriage, we are often inclined to regard the personal happiness of the married couple as the purpose of their union Human marriage is, no doubt, at its best a pure and noble source of joy, but it is this indirectly rather than directly When we take the happiness of two married people as the supreme and only test of the success of their marriage, we are but mistaking one of the means for the crowning end, and when we do this there is considerable danger of our going so far as to stop half way down the road that nature meant us to follow to the finish

To put it in another way, happiness in marriage is like the reward a good workman receives for undertaking a difficult duty But, in regard to the maintenance of the species, the care and the trouble and the expense of looking after the young must be undertaken even where there is no material reward Ibsen, Strindberg and their followers do not mean well when they point out the limitations of marriage, their cynicism is based on a love of pleasure and a dislike of the duties and responsibilities of married life

However in so far as their criticisms serve to bring out the fact that marriage is fellow-service and the joys of fellow-service, rather than a refined form of selfishness, they help to clear away a mist of romantic falsities, and assist us in seeing the problem in a clear light

Let us, for argument's sake, be willing to admit that modern marriage is a failure. Certainly the number of those who are able to set up for themselves in life is growing, while the number of those who undertake the highest duties of the race seems to be diminishing.

This is the veritable problem of modern marriage. The growth of luxury is spreading among our people a base and narrow selfishness. Our literary pedants put it that marriage prevents men and women from developing their individuality and cultivating their finer powers to the uttermost. More ordinary cynics say that it would hinder them in their career and make them less successful in life. So the individual *apparently* enjoys more luxury, and the race decays. He owes his existence to the sacrifices of his ancestors, but he is too selfish to hand down the torch of life.

The great empires of the past which forgot their children

Some of the most splendid civilizations have failed because the interests of the child were overlooked in the pursuit of apparently other high aims. The achievements of the ancient Greeks, for example, are, from an historical point of view, of very great importance; but the intellectual, artistic, and political triumphs of Greek civilization in the days of its supreme power must have seemed of little importance when looked at through the eyes of Greek children a few hundred years afterwards. The welfare of the race had been neglected, and so the glory of Greece passed away like a pageant of sunset clouds. If, in the struggle for the dominion of the world, the children of the Romans had been also lost sight of, the civilization of Greece, which the Romans adopted and handed down, might to a large extent have been lost to humanity. In course of time, Rome also became too busy to look after her children, with the result that a good deal of her work would not have survived if the Teutonic and Mohammedan races had not retained the simpler and more important view of the function of human life.

The seeds of ancient destruction now at work in the modern world

For nearly fifteen hundred years the nations with their ancient seat in northern Europe have carried on the work of civilization, and at the same time kept in view the interest of the child. By these two means they have spread over a large part of the earth, and advanced in a wonderful manner the power and knowledge of man. Now, however, they seem to be going the way of Greece and Rome. Under the present conditions of civilized society, where any capable man and woman can, by devoting the whole of their energy to the task of making money and enjoying the pleasures of money, live in comfortable singleness all their lives without exciting the scorn of their neighbors, marriage may be regarded as a failure — if examined entirely from an individual selfish point of view. Sheer self-regarding prudence of this sort is at present not uncommon; it extends in every nation with the growth of luxury, and it was one of the chief causes of the downfall of the most brilliant civilizations of the past.

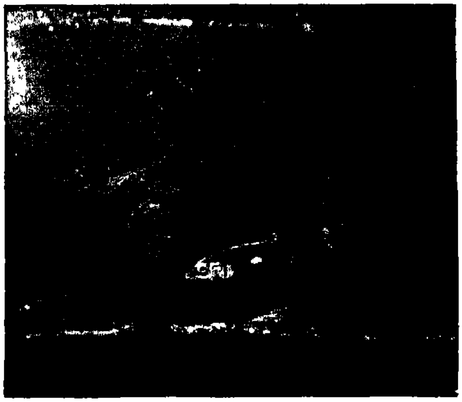
Great poets and novelists celebrate the love that leads to marriage. What they do from the instinct of genius, the great thinkers do from the larger reason. For they see that the individual must be subordinated to the needs of society. But little modern realists, studying life from a personal standpoint only, manage to express the ideas of an ignoble crowd of modern men and women who have lost their natural instinct and failed to arrive at the larger reason for its existence. Happily, all fine things in life are unreasonable from a self-centered point of view — heroism and self-sacrifice, as well as love and marriage; and perhaps if we study marriage from a scientific point of view, without confusing the pleasures of luxury with the joys of parenthood, we shall find that it is not a failure. Self-development and self-assertion cease to be hostile forces when each self is seeking the fulfilment of its own purposes and its fullest development, in a common end — whether that end be married life or some other.

Nature has not always ruled that the union of the sexes should be a long and high source of pleasure to the parents. The interests of the offspring are supreme. Among several of the lowest forms of life, sometimes a mother and sometimes a father is sacrificed to the interests of the species. When the cochineal insect, for instance, is about to bring forth young, it dies, leaving the shell of its body as a protective envelope for its offspring. Thus, while in one sense the welfare of a species depends upon the welfare of its individuals, in another sense the welfare of the species entails some sacrifice of the welfare of its individuals.

Among many of the lowest forms of life the greater part of the burden falls upon the young, which perish in immense numbers. A codfish produces above a million eggs, and survives to do this year after year. But while the life of the parent is preserved, nine hundred and ninety-nine thousand and more of the progeny die before maturity. Even among fishes, however, we find the burden of maintaining the species more fairly divided between the parents and the offspring. The parents build nests for their young, and, like the brave little stickleback, watch over them and guard them. As a rule, the need for parental care increases at every step upward in the scale of life. Either the mother or the father — and often both — must devote an increasing amount of time and care to bringing up the young and defending them from creatures of prey. Thus from an intensely selfish point of view marriage is a failure even among the animals.

Nature, however, is generous to the poor beasts of the field who faithfully undertake the duties imposed upon them. The longer the period they give up to the care of a single brood, the longer becomes the period in which they are able to live for their own sake. In the highest class of animals, the mammals, regarded as a whole, we see a general advance in this conciliation of the interests of the race, the parents and the young. We see it also within the class itself on ascending from its lower to its higher types.

Thus the small rodent arrives at full growth in a few months, and, after producing large and frequent broods, it soon dies. There is but a short early period during which the female lives for herself; and as she usually loses life before she is past her prime, she enjoys no latter days unburdened by offspring. Turning to the other extreme, among the mammals, we find an immense contrast. From twenty to thirty years of the life of a young elephant are passed entirely in personal development and activity. Offspring are produced in few numbers and at long intervals, and the tax of bearing them thus falls lightly on the adult female while the male throughout his very long life is scarcely inconvenienced.



THE STICKLEBACK GUARDING ITS YOUNG
The brave little stickleback builds a nest for its young in the bed of a river or a pond, and guards them from enemies.

It was long ago pointed out that the domestic relations which are reckoned the highest from a moral standpoint will be found to be those most efficient in a scientific view. It is this inspiring coincidence which we must now trace. In a former chapter we dealt with the relations of the sexes chiefly in regard to their bearing on the conditions of the men and women who entered into them. Keeping to the ordinary outlook, we indicated the steps by means of which the mothers and fathers of the race were benefited as they advanced from irregular unions to permanent marriages of one man with one wife. This, however, was rather a superficial survey. In the end it is the child who attests the value of the marriage from which he is born.

In this case the happiness of the parents does not count, except in so far as it has a direct bearing on the welfare of the offspring. It is only the actual way in which the parents have carried out their duties that tells on the child and makes him the living testimony of their qualities.

Beginning with the effects of promiscuous unions, we need not turn, unhappily, to savage races or to barbaric times to find in the child a victim of all that is worst in human nature. The utter negation of parenthood is seen in the foundlings of our great cities; they are the most pitiable and the most appalling evidences of an age of pleasure-seeking cowardice.

The "children of the fatherland" denied by their parents

Probably nothing in the world makes a stronger appeal for pitying sympathy, or incites to greater condemnation of the perverted moral standards of civilized life, than the fate of a helpless, abandoned baby. Yet in every modern nation they are numbered by the thousands every year. People who shrink in horror from overt murder, who perhaps have not the courage quickly to dispatch a disabled dumb animal or one wanted for food *when they have to be direct witnesses of the action*, readily take the responsibility for acts which mean murder by slow and cruel processes of the most helpless and appealing as well as most precious of living things. They may know what is involved in their conduct, but so long as they do not have to *see* it they are not greatly perturbed. There is no way of learning the number of deliberately abandoned foundlings. In France these *enfants de la patrie*, or "children of the fatherland," as they are prettily called, are said to number 150,000 per year, but this may include natural orphans in addition to the victims of human vice and selfishness.

In the United States we have no knowledge of the number of foundlings, and provision for them, like our charity and relief work in general, is left to the state or municipality. Local investigations have shown that conditions are sometimes most revolting and terrible.

In this connection, only a few years ago an inquiry in Baltimore disclosed the existence of thriving institutions whose function it is to take charge of undesired new-born babies, taking care of the mother when confined, if so desired.

The result was nearly certain death — only a few lived beyond two or three months — and one of these "hospitals" is estimated to have buried more than five thousand in one plot of ground a few square rods in extent. No doubt similar conditions exist in every considerable city in the "civilized" world. In any impartial view of the case, such procedure is infinitely worse than merciful killing, or even than exposure as practised in ancient times and in Eastern nations today.

Many of these children should never have been born; the crime of the parents goes farther back, to the bringing into the world of children who will have no normal home to grow up in nor ordinary parental care. Of course, not all illegitimate children are abandoned, nor are all foundlings illegitimate, but there is a general connection between the two classes. Moreover, the home life of any illegitimate child is sure to be abnormal, and hence it is important to consider the extent of illegitimacy in modern communities. As an indication of the standards of sex morality, the best measure of the amount of illegitimacy is the proportion of such children to the unmarried women of child-bearing age, say from fifteen to forty-five years. But from the standpoint of the child, which we are now considering, it is better to study the percentage of illegitimate births.

However, here again the figures for our own country are not available, but we are astounded to learn that in many of the great nations of Europe, such as France, Germany, Austria and the Scandinavian countries, something like one child in ten is born out of wedlock. In the city of Stockholm the proportion is more than one-third, and in Vienna nearly one-half. Investigations have shown that the death-rate for such children is often double that for the legitimate, and that the percentage of criminality among those who survive to adult years is very much higher.

The social importance of securing proper home surroundings for every child is forcibly brought out by the history of the illegitimate. However, it is foolish to add to the inevitable handicap the further gratuitous ones of legal disabilities and social stigma. The child, innocent of wrong, should be given every aid and encouragement, and the condemnation and punishment visited upon his "unnatural" parents.

How modern liberty runs into license and the family bears the burden

In earlier days when the mode of living of the masses was much more fixed than now, such a thing as desertion of the family by the husband and father was almost unknown. Conduct in general was closely prescribed by custom and ways of making a living; even means of conveyance were more provincial than now, people were suspicious of strangers, and wanted to know the life-history of those they dealt with. At that time, if a man did abandon his wife and children to the mercies of the world and go to seek his fortune in other regions, he found his way difficult, and was nearly sure to be brought back and publicly whipped. Now all this is changed, and in another case the cost of freedom is often borne by the helpless members of the community, the mothers, and especially the children. There is an alarming increase in destitution resulting from the abandonment of wife and children by the breadwinner.

Some years ago a Scotch divine of Glasgow became interested in the deserted families of that city, and made a general investigation. He found that a considerable proportion of the men who emigrated to America and to other distant regions permanently left their families, often even marrying again and bringing up new families in the country of their adoption. The United States Bureau of Immigration and the various private organizations for immigrant aid are constantly troubled with complaints and inquiries for "lost husbands," and within a great nation like ours the opportunities for such conduct are far too great and inviting.

We can form but little judgment of the extent of the evil on the whole, yet some known facts prove that it is very great. The National Conference of Jewish Charities a few years ago established a National Desertion Bureau, which handled 652 cases in its first year of work, in connection with Jewish immigration to New York City alone. Again, the Juvenile Court of the District of Columbia handled nearly a thousand cases in a single year, and the Chicago Court of Domestic Relations dealt with 900 in the first year of its establishment. This court represents a step in advance over anything else in existence in the effort of a modern community to cope with this particular evil. But in every state in the Union non-support has been made a crime, and public and private agencies are working toward the enforcement of this primary parental responsibility.

Financial support, however, is by no means all that a father owes to his family, or that the parents jointly owe to their children. Hence we must raise the question as to how much has been done to cure the fundamental evil when the law has enforced regular and adequate money payments, and perhaps granted to the wife and mother a divorce with alimony. This leads us to consider the subject of divorce, which is such a burning question in present-day America.

Is the belief in marriage weakening in the United States?

One of the most startling phases of the modern era of personal freedom and individualism is an apparent tendency to lessen the stability of family relations. This is particularly striking in our country, where the whole individualistic movement has made extraordinary progress. We have shown the world the way to liberty; is it to be the way to destruction? It is the opinion, or at least the fear, of many conservatively minded people who are alarmed at the frequency and the rapid increase of divorce in the United States, that such will be the result unless something can be done to check the present tendency.

Today the divorce-rate in this country — *i.e.* the number of divorces granted in one year in proportion to the population — is more than twice that of any other Christian nation, and seems to be increasing more rapidly as well. The absolute number of divorces per year is more than twice that of all other Christian nations combined. It is worth noting also that the next in order of the Christian nations in this respect is Switzerland, and that in general the divorce-rate is high where there is a strong sentiment for individual liberty. The rate of increase in the number of divorces is still more striking. During the fifty-seven years for which the figures have been collected in the United States, or from 1867 to 1924, it has multiplied more than five times, rising from twenty-seven to one hundred and fifty divorces per 100,000 population. Comparing successive decades, we find a nearly uniform increase of about seventy per cent in each decade over the preceding one. A part of this growth, however, must be accredited to the increase of legal divorce among the negroes of the South, in place of voluntary and informal changes in family relations, and this assuredly testifies to a rise and not a decline in the moral sense.

Civilization and the home. The permanent monogamous family

On their face, these facts seem to afford every justification for alarm. Modern civilization rests on the monogamous family. Society depends upon its homes for the training of its citizens in the habits and virtues essential to social life. Every civilized nation of today rests upon this basis, and all peoples that have made important contributions to modern civilization, or even risen out of barbarism, have had a definite organization of the father-family principle. In some barbarous peoples the mother is the dominant member of the family. Names are transmitted and property inherited through her, and the husband becomes a member of the wife's clan and not the reverse. In a few cases we find a woman married to several husbands, an extraordinary system known as "polyandry."

At the present time, however, all the culture races have evolved out of the "mother-law" stage, and developed a family dominated by the father, and often including several wives, who are virtually his property.

The effect of the marriage system on competition between peoples

The polygamous form of society seems at first glance to have many advantages. It does not decrease the birth-rate, or at least not seriously. In general the men able to secure a number of wives, whether by persuasion, purchase, or force, would tend to be the superior individuals, while those left unmated would be the weaklings, as a rule, and this should lead to the improvement of the race. In some primitive tribes where the males are continually decimated by warfare, it may be really necessary to keep up the population. Nevertheless, the most advanced nations have gotten rid of polygamy, and adopted pair marriage as the only legal basis of sex relations. The polygamous system has two main disadvantages, which probably account for its being supplanted. In the first place, it degrades woman, who becomes a chattel rather than a companion, even where the mothers have separate households. Connected with the degradation of woman, but vastly more significant from the social standpoint, is the effect on the children. The jealousies, intrigues, and quarrels of the polygamous family tell on the character of the mother and divert her interest from her children, who also suffer from the lack of paternal care and companionship.

Thus, when other things are equal, a polygamous nation goes down before a monogamous people, whose men have been better disciplined and better instructed. The great principle of the struggle for existence and survival of the fittest which Darwin showed to hold good in biology, leading to the progressive evolution of animals and plants from lower to higher forms, holds good also between societies. It works itself out not only in trial by battle, but in every form of human competition.

Still, it is doubtless true that the great modern polygamous races do not practice polygamy on a large scale; it is only their chief men who have a plurality of wives. It is, however, these chief men and their children on whom falls the task of directing the policy, the civilization, and the industrial expansion of the country. Against them are ranged men brought up in the higher school of single marriage. That is why, for the last three thousand years, victory has inclined at last to the side of the monogamous nations.

What does the increase in divorce mean, lower tone or higher standards?

It is easy to argue from the increase in divorce that America, the home of liberty, is returning to polygamy or promiscuity, and that our civilization is doomed. Yet such is not the conclusion drawn by Professor W. F. Willcox, who has made a careful study of the question. Society, as we have repeatedly emphasized, is interested in the family chiefly on account of the children. Now, in the first place, it is pointed out that probably four-fifths of the divorces are granted to childless couples. It is notorious that dissension between husband and wife is more likely to occur when there are no children to create a strong common interest and bind them together. Again, two-thirds of American divorces are granted on the application of the wife.

Therefore it is obvious that the number of divorces might easily increase where dissension, desertion, unfaithfulness and the grounds of divorce generally, were actually decreasing. There is some indication that a connection exists, in fact, between the amount of divorce and the general position of woman in society, the amount of submission and subservience she is required to show her "lord and master," and the amount of abuse and mistreatment she must accept before the law will grant her relief. Along the same line is the proved relation between the divorce rate and the cost of divorce proceedings. In Europe these are purposely made difficult and expensive, and in consequence divorce is a luxury that can be afforded only by the rich.

It is true modern society, particularly in America, has relatively little reverence for tradition, and is disposed to regard facts rather than forms. But is this a lowering or a raising of standards? Where the substance of home life is impossible, is there any particular virtue in not recognizing the fact and fitting the form to it?

It has been said that the divorce system is a sort of legalized polygamy or promiscuity, and American society is compared with that of the decadent Roman Empire. Here, again, the statistical facts available are against the prophet of evil. It is a common opinion, often stated as a fact, that divorce is usually desired for the purpose of contracting a second marriage. But the figures show that divorced persons are not appreciably more likely to contract a second marriage within a given interval than are widows and widowers. When we add to this the fact that complete separation of the parties takes place on the average more than one and one-half years before the granting of divorce, the evidence for the breaking up of homes by third parties becomes shadowy. As far as nominal home life is concerned, it is the separation that is important; the legal decree is a mere form. But real, socially desirable home life demands much more than living together, and it is clear that we can finally dismiss divorce statistics as a proof of deterioration in the quality of the home life.

Are the leading nations of the world committing race suicide?

In connection with modern family life, an apparently more real cause for alarm than the increase of divorce is found in the decline of the birth-rate. France affords the stock "bad example" in this respect, but the leading nations differ only in degree. It is true that the French population is probably not holding its own if immigration be deducted, but there are good indications that the birth-rate of the native population in the United States is quite as low as that of France, and in the other nations of European civilization it is rapidly declining. The fall in the birth-rate is not necessarily an evil.

The progress of medical science, increase in wealth and rise of the standard of living of civilized peoples have led to a phenomenal decrease in death-rates, and a corresponding decrease in the number of births is necessary if population is not to increase abnormally, giving rise to overcrowding and robbing humanity of the fruits of the general advance. When births actually fall below deaths, however, as they have already done in France, the situation is disquieting. It is, perhaps, too early to say whether this shirking of family responsibility is an inevitable product of modern conditions, or whether it is temporary and transitional.

In the United States in particular, though the same holds in some degree of other countries, observers are more concerned with the "differential fecundity" or relative rates of increase or decrease in different elements of the population. Many persons believe that in the highly civilized states the race tends to deteriorate in quality through the failure of the more capable and enterprising strains to reproduce themselves, while the less capable increase rapidly. It is pointed out that celibacy or very small families are the rule among those conspicuous for achievement in all kinds of constructive work, while the growth in population is contributed by the ignorant and inert masses, and even the actually degenerate increase with startling rapidity. Careful studies of Massachusetts data by Dr. R. Kuczyinski, and of New Hampshire figures by Professor A. A. Young, indicate that the birth-rate of our native population is only about half that of the recent immigrant classes, and that the former is actually dying out. Professor Young's investigation proves conclusively for the population studied what is believed to hold true of the declining birth-rate in the world generally — namely, that it is due to voluntary restriction, and not, as some physicians have argued, to any physiological sterility in civilized women. The nature of the cause is a bit disheartening from the moral standpoint, but at least it opens up the possibility of remedial action by society. These are questions the modern nations must face.

THE DENIAL OF PARENTAL RESPONSIBILITY — "THE FOUNDLING" BY HENRY HENSHALL
The Foundling Hospital in London, established in 1739 "to suppress the inhuman custom of exposing new-born infants to perish in the streets," receives every year about five times as many applications as it can grant.

GEOLOGISTS

GEORG AGRICOLA — THE FATHER OF MINERALOGY
LEOPOLD VON BUCH — A CHAMPION OF FIRE AGAINST WATER
THOMAS CHROWDER CHAMBERLIN — AN AMERICAN STUDENT OF GLACIERS
JAMES DWIGHT DANA — THE IRON HEART OF THE WORLD
SIR JOHN WILLIAM DAWSON — A CANADIAN OPPONENT OF DARWIN
GRATET DE DOLOMIEU — FOR WHOM STONE WALLS DID NOT A PRISON MAKE NOR IRON BARS A CAGE
CLARENCE EDWARD DUTTON — DISTINGUISHED AMERICAN SOLDIER, GEOLOGIST AND SEISMOLOGIST

GEORG AGRICOLA
The Father of Mineralogy

GEORG AGRICOLA (the latinized form of the German name Bauer) was born at Glauchau, in Saxony, on March 24th, 1490. He entered the University of Leipzig in 1514 at a time when the humanistic movement was very popular there, and embraced the new learning with such eagerness that four years later at the age of twenty he became principal of the municipal school at Zwickau in his native Saxony. At first Agricola's bent seems to have been towards the study of languages, for he taught Greek and published a Latin grammar from Zwickau and then gave up his appointment to continue his studies in philology at Leipzig. But probably on account of the mining region in which he lived his interest was attracted to the study of natural sciences. He traveled to various universities in Italy, and there took his doctor's degree. In 1527 he set up as practising physician in the ancient town of Joachimstal in the Erzegebirge, where there were valuable silver and coal mines, and devoted his leisure to the investigation of ores and their treatment, publishing in 1528 "*Bermannus*," his first work on mining. Prince Maurice of Saxony, one of the ablest diplomats, administrators and generals of the age, appointed Agricola in 1530 to be historiographer, and in order to widen the range of his observations in mineralogy he went to Chemnitz, where he resided until his death on November 21, 1555.

Agricola was a stanch and loyal Roman Catholic, but Chemnitz was violently for the Lutheran creed, so that although he was for three years burgomaster of the town and emissary to Charles V from the Elector, the citizens refused him burial, as was his right, among the remains of other burgomasters in the Protestant church of St. Jacob, and, amidst hostile demonstrations, he was borne to Zeitz for interment in the cathedral there.

Agricola's most famous work, "*De re metallica*," consisting of twelve books covering mining, metallurgy and geology, well and interestingly illustrated with wood cuts, was not published until after his death, though completed some years before. It was translated into German, Italian and English, and ran through many editions. It marks him as one of the most accomplished chemists of his time, and was the standard authority for miners and metallurgists for nearly two centuries, being the first systematic description of methods and processes based on research and observation instead of the speculations of his alchemist predecessors.

Besides this and several smaller works on the metals, Agricola published (1546) a great work on the nature of fossils, in ten books, which is the first systematic attempt at the subdivision of mineralogy, and is worthy to rank with his "*De re metallica*," and he followed it with an account of subterranean phenomena in five books in which he laid the first foundations of physical geology. It was he who introduced the term "basalt" into the scientific vocabulary of petrology.

LEOPOLD VON BUCH
A Champion of Fire Against Water

CHRISTIAN LEOPOLD VON BUCH, one of the greatest of German geologists, was born at Stolpe, in Pomerania, on April 26, 1774, of a noble and rich family. Sent at the age of sixteen to the Mining Academy of Freiberg, he lived there in the house of Professor Werner, a famous mineralogist and teacher, and formed a lifelong friendship with the illustrious Humboldt, who was a fellow-student. During this time, and his succeeding courses of study at Halle and Göttingen, Von Buch investigated the neighboring regions. He received a government office appointment, but held it only a few months and thus regained his liberty in 1797 to give his life to geological travels.

Among the regions through which he wandered, studying the rocks, were Silesia, in 1796; the Alps, Italy, and especially the neighborhood of Rome and of Naples, in 1798; the Canton of Neuchâtel and the Alps and Jura Mountains, from 1799; Auvergne, in 1802; Naples, in 1805, where, with Gay-Lussac and Humboldt, he saw Vesuvius in eruption; the following year, until 1808, Norway and Lapland; then for some years the Alps again; the Canary Islands, in 1815; Scotland, for the West Highlands, and especially Staffa and Fingal's Cave, in 1817; then almost every year the Alps, though occasionally other parts of Europe. He lived in Berlin, where he was socially of high rank, and had great influence; and there, on March 4, 1853, he died. Professor von Zittel, describing his travels, says: "Most of his Alpine journeys were accomplished on foot. Clad in short breeches, black stockings, and buckled shoes, the pockets of his black coat stuffed with notebooks, maps, and geological tools, his tall, imposing figure was bound to attract attention. His traveling luggage was limited to a fresh shirt and a pair of silk stockings. His physical endurance was only surpassed by his iron determination, which could overcome all difficulties and discomforts. Socially, he was everywhere beloved; his aristocratic bearing, his mastery of foreign languages, his wide knowledge of science and literature, all combined to make him one of the most agreeable companions."

Leopold von Buch was a geologist with a universal interest in his favorite science, but his greatest contribution to it was the demonstration of the part which igneous and volcanic action had played in the formation of the rocks. Werner, his friend and teacher, had unduly extended the importance of aqueous action, regarding basalt, for instance, as a sedimentary deposit, and explaining volcanic activity as due to the combustion of deep-seated coal. Again, Werner regarded mineral veins in rocks as due to the descent, from the surface of the earth, of water loaded with minerals in solution. This Neptunian theory had a great vogue in Germany, but was disproved, or rather, restricted to its right place, by the labors of Humboldt in Central and South America, and of Leopold von Buch in Europe and the Canary Islands. But the latter's many papers and books dealt also with the most varied geological questions. His geological map of Germany, involving enormous labor, is a classic. "Through Norway and Lapland," besides descriptions of the rock strata, includes studies of the climate of those regions, — of the raised beaches of Scandinavia, which he regarded as due to a rising of the coast, and not to a falling of the sea-level; and of the Scandinavian rocks from which the ice had brought boulders to the German plains. "A Physical Description of the Canary Islands" is a profound study of volcanic action that has there been at work on a vast scale. Many of his later papers are devoted to the fossil forms of ancient mollusks.

Leopold von Buch wrote of the scenes he interpreted in a peculiarly vivid and picturesque way. He was a great mineralogist, but was far more than a dry-as-dust breaker and classifier of stones. He was artist as well as scientist, and scenery and geology were for him a living unity, so that landscape became significant of the structure of the rocks. This power of vision is reflected in the vigor of his style.

THOMAS CHROWDER CHAMBERLIN
An American Student of Glaciers

THOMAS CHROWDER CHAMBERLIN, one of the most accomplished of American geologists, was born at Mattoon, Illinois, on September 25, 1843. He was graduated at Beloit College in 1866, and after four years as a teacher of natural science in the state normal school at Whitewater, Wisconsin, was appointed professor of geology at Beloit, a position which he held from 1873 to 1882. From 1885 he was for two years professor of geology at the Columbian University, Washington, and was then appointed president of the University of Wisconsin. Since 1892 he has been professor and head of the department of geology in the University of Chicago, and, from 1902 was connected with the Carnegie Institute as investigator of geological problems. He accompanied, as geologist, the Peary Relief Expedition of 1894.

Professor Chamberlin's most important work is in connection with glacial action. He made, in 1878, a study of the Swiss glaciers, and was in 1882 placed in charge of the glacial section of the United States Geological Survey. While engaged in this active work he collected and published a vast amount of new material relative to the character of the glacial deposits in the Northern States, upon which he based some interesting theories His studies of modern glaciers have also yielded scientific results of a high order. The planetesimal hypothesis, which he formulated with Moulton as an explanation of the origin of the planetary system, has commanded general attention in the scientific world.

Dr. Chamberlin was president of the Geological Society of America in 1894 and of the American Association for the Advancement of Science in 1908. Among his more important books may be mentioned "Our Glacial Drift," "Geology of Wisconsin," "The Origin of the Earth" (1916) and, in collaboration with Professor R. D. Salisbury, "Geology," in three volumes (1904–1909), and "Introductory Geology" (1914). He was at one time editor of the *Journal of Geology.*

JAMES DWIGHT DANA
The Iron Heart of the World

JAMES DWIGHT DANA, one of the most eminent scientists of the nineteenth century, was born at Utica, New York, on February 12, 1813, and was educated at Yale, where he studied especially mathematics, physics and chemistry. Thanks to an appointment in 1833 as instructor in the United States Navy, he had the early advantage, not so common in those days of European travel, and the first of the many scientific papers that he was to contribute to the *American Journal of Science* was an account of Vesu-

JAMES D. DANA

vius, written during a Mediterranean cruise. In 1836 he returned to Yale and became assistant to Professor Silliman, and published his first important book, "The System of Mineralogy," which in many editions remained a standard work and gave him a European reputation. In 1838 he was chosen to accompany the Wilkes Exploring Expedition, sent out by the United States government, as geologist and mineralogist. In the course of the voyage along the coasts of South America and among the islands of the Pacific, Dana collected a vast amount of zoölogical and geological material. He was wrecked on the coast of Oregon, but sailed again

from San Francisco, by way of Singapore and St. Helena, to New York, thus circumnavigating the globe. The spoils of these four ocean-years took more than three times as long to study and describe in his celebrated works, "Reports on Zoophytes" (1846); "Report on the Geology of the Pacific" (1849); and his "Report on Crustacea" (1854).

In 1850 Dana was appointed professor of geology at Yale, and served till within three years of his death, which occurred on April 14, 1895. His was the predominant influence in forming the brilliant American geologists and physiographers who have succeeded him. He was a man of large mind, vast knowledge gained at first-hand in the study of nature, and bold conceptions. His belief, for which there is much to be said, that the earth is elongating in the direction of the poles and contracting in its equatorial diameter, is, whether true or not, an example of a simple conception which unites many diverse phenomena. A similar example is his theory of the constitution of our globe — that two-thirds of its mass consists of iron, forming a rigid core or nucleus, surrounded by a hot, viscous envelope of molten rock-stuff, the whole being inclosed by a solid, hard crust about seven miles in thickness.

Volcanoes and volcanic action always interested Dana very deeply; he was the first, in 1840, to give a scientific account of the strange, silent volcanoes of the island of Hawaii, with their giant cones; and one of his last and most important works was the "Characteristics of Volcanoes with Contributions of Facts and Principles from the Hawaiian Islands," published in 1890.

Coral reefs were also a subject of prolonged, careful study; he was a strenuous supporter of the theory that reefs and atolls are formed during the gradual subsidence of the sea bottom — a view which has been as vigorously contested by many. Whichever hypothesis turns out to be true, or whether, as is probable, various coral reefs are formed in various ways, Dana's "Corals and Coral Islands" (1879) will always remain a classic.

But Dana's greatest contribution to geological science is unquestionably his explanation of the origin of mountains by the crumpling of the earth's crust caused by lateral compression. The theory was outlined by his papers, as early as 1846, in the *American Journal of Science*, of which in that year he became the lifelong editor. It is the chief example of his extraordinary power of bold and simple conception, associated with close investigation of all the related facts of every kind. The hypothesis, or rather the now established scientific principle, was suggested to him by an intimate study of the Appalachian Mountains, which are excellent models of rock-strata crumpled and thrown up by the enormous horizontal compression consequent upon the shrinking of the earth's interior. In the study of this subject Dana was helped greatly by the collaboration of Le Conte, and other American geologists contributed studies from the Rocky Mountains and elsewhere in support of it, but the credit of discovering the chief cause of mountain structure undoubtedly belongs to Dana.

The life of this wonderful scientific worker, like that of Humboldt, Bates, Wallace and many others, teaches that the way to understand the face of the world is to go out and see it.

SIR JOHN WILLIAM DAWSON

A Canadian Opponent of Darwin

THE most distinguished of Canadian geologists was born at Pictou, Nova Scotia, on October 30, 1820. He was educated at Pictou College and Edinburgh University, where he was graduated in 1842. In the same year he joined Sir Charles Lyell in a geological study of Nova Scotia, returning in 1846 to Edinburgh to study chemistry. He worked again with Lyell, in 1852, in an investigation of the carboniferous vegetation — Dawson's chief field of research — when they brought to light reptilian remains of great interest.

Appointed, in 1850, superintendent of education in Nova Scotia, and in 1855 vice chancellor and professor of natural history in McGill University, Dawson

effected, by his zeal and public spirit, a great advance in the standard of Canadian education. For many years he lectured on natural science at the McGill Normal School. He founded the Royal Society of Canada, and was its first president. He was president of the American Society for the Advancement of Science in 1882, of the British Association in 1886 and of the Geological Society of America in 1893. He had received a gold medal from the London Society in 1882, and was an honorary member of many of the European learned bodies. He was knighted in 1884.

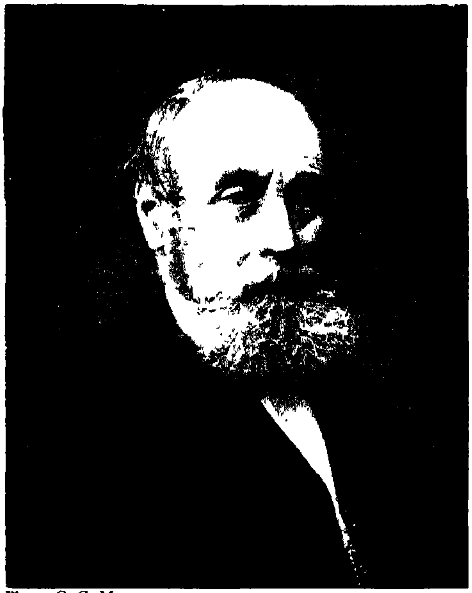


Photo C. G. Mason
SIR JOHN WILLIAM DAWSON

It is unfortunate that the name of Dawson, who carried out very brilliant geological work, should be generally associated with an error. MacCulloch had found, in 1858, in the Canadian Laurentian gneiss, very remarkable combinations of serpentine and calcite, in which the serpentine was ramified through the calcite in a curiously reticulated way, strongly suggestive of a foraminiferous growth. Dawson described it as such, in 1864, under the name of Eozoon Canadense; and the supposed discovery attracted great attention, because Eozoon was obviously, from the nature of the rocks in which it was found, the earliest of all organic fossil remains. Many high authorities supported Dawson's view, but Moebius of Kiel finally proved that the structure was of inorganic origin.

Dawson was an able controversialist and a keen opponent of the Darwinian theory. Besides many scientific papers, he wrote several more popular works, including "The Dawn of Life" (1875); "The Origin of the World" (1877); and "The Meeting-Place of Geology and History" (1894). He died in Montreal on November 20, 1899.

GRATET DE DOLOMIEU

"Stone walls do not a prison make nor iron bars a cage"

DÉODAT GUI SYLVAIN TANCRÈDE GRATET DE DOLOMIEU, a distinguished French geologist and mineralogist, was born at Dolomieu near Tour-du-Pin, Department of Isère, France, on June 24, 1750. Admitted from the cradle into the order of the Knights of Malta, commissioned as an officer of the Carabiniers at 15, and entering upon his novitiate at 18, he did not seem destined by Providence to devote the greater part of his career to science, but accidents of his youth changed his life, and amid the misfortunes of his later years science was to prove his consolation. At an early age he fought a duel and killed his opponent, a brother knight. In consideration of his youth, but only after long delay, he was pardoned. During a tedious imprisonment he began his scientific studies; in the garrison where he was confined he worked with the Duc de la Rochefoucault, who, on his return to Paris, induced the Academy of Sciences to make Dolomieu a corresponding member. Upon his release, desirous of continuing his researches, he made journeys into Portugal, Spain, and Sicily, and in this island began his long-continued devotion to the study of volcanic action. Returning, he revealed to the Grand Master a rumored plot of the Neapolitan and Russian courts, of which he had heard in Italy, to take possession of some of the ports of Malta. The Neapolitans learned of Dolomieu's action in the matter, and thereafter he was forbidden to enter the kingdom of Naples, and through the same influence hindered from becoming a councilor of his order.

He appealed to Rome, and after a lengthy trial obtained restitution of his rights, employing the intervals between the courts for journeys through Italy to examine the composition of its mountains, and only returning to Malta to acclaim his victory and deposit his collections. Through the stormy years of the Revolution, Dolomieu, like many another idealist, was disillusioned: his friend the Duc de la Rochefoucault was assassinated in 1792, almost before his eyes, and for several years after Dolomieu lived with the duke's family in retirement at Roche-Guyon, only coming to Paris to take note of the times. With the end of the Reign of Terror, he began again his geological excursions through France, always on foot and hammer in hand. Upon the announcement of Napoleon's expedition to Egypt in 1798, ignorant of its full design, Dolomieu was possessed with a desire to visit the country in which geology was born, and became one of the scientific advisers to the General. When Napoleon seized Malta from the Knights of St. John, the former Knight and Companion of the Order was overwhelmed by the realization of his own innocent participation in such an act of treachery. Haunted by reproach Egypt was spoiled for him. Rapidly he covered the country occupied by the French armies, but was then reduced to inaction because the position of the troops did not admit of extensive exploration. He lost his health and determined at all costs to return to France. Like Richard Cœur-de-Lion he suffered shipwreck, and was left at Messina, where he was still an object of hatred to the government. Arrested and thrown into a filthy cell, writing materials were denied him, but with a pen fashioned out of a piece of wood, and using the smoke from his lamp for ink, he wrote on the margin of his Bible his "*Traité de philosophie minéralogique*" and "*Mémoire sur l'espèce minérale*." Efforts of his friends to free him were in vain, and he was not released for twenty-one months, when peace was concluded between France and Naples.

On his return to France he found that the chair of mineralogy at the Museum of Natural History in Paris had been waiting for him for two years. The interest that his captivity had inspired doubled that of his lectures, and the attendance was prodigious, throughout this his only course. Seeds of the illness sown by his imprisonment were hastened to maturity by a journey into the mountains of Switzerland, Savoy and Dauphiné made during the autumn of 1801, and on his return he died in November of the same year.

Besides the works written in captivity he published several books on volcanoes and earthquakes.

CLARENCE EDWARD DUTTON
American Soldier, Geologist and Seismologist

MAJOR DUTTON was born at Wallingford, Connecticut, in 1841, graduated from Yale in 1860 and was an officer of volunteers in the Civil War. At its close, he devoted himself to the study of geology and, in 1875, accompanied Major John W. Powell's Rocky Mountain survey as assistant geologist. He was connected with the U. S. Geological Survey from 1880 until 1891, being in charge of the department of volcanic geology and seismology after 1887; was promoted to the rank of major in the army in 1890, retired in 1891 and died in 1912.

In Dutton's investigation for the U. S. Geological Survey of the Charleston earthquake of August 31, 1886, he devised and adopted a new method of ascertaining the depth of the focus, and this, and his observations on the nature and speed of earthquake waves, published in the government report, attracted wide attention and helped develop scientific interest in the study of seismology.

He it was who suggested the use of the word "caldera" (Spanish for "cauldron") for the broad, shallow pit craters, with almost perpendicular walls and horizontal stratification, such as appear in basaltic cones like those of the Sandwich Islands. He regarded them as having been formed by the subsidence of the walls.

Dutton was a member (1884) of the National Academy of Sciences. He wrote a number of books on earthquakes and volcanoes and on the geology of North America.

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